THE BEAMA JOURNAL

AUGUST 1960

A British-built electric locomotive on the Spanish National Railways

A QUARTERLY REVIEW OF
BRITISH ELECTRICAL AND ALLIED ENGINEERING

Special Feature in this issue: Electric Traction

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Cover Illustration. *One of the English Electric 3 600 hp 3 000 V d c electric locomotives in service with the Spanish National Railways hauling a mixed traffic train at Los Corrales (Santander-Alar del Rey).*

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A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

Volume 67 : Number 3 : August 1960

The British Traction Industry

The year 1960 will be made outstanding by the forthcoming British Railways Electrification Conference and Exhibition to be held in London from 3 to 9 October, of which preliminary details are given in pages 110 and 111.

It may seem somewhat paradoxical that, while British-built electric and diesel-electric locomotives and trains are to be found in considerable numbers on the railways of many countries in the world, the trains on most of the railways in Britain itself were, until recently, largely steam hauled.

This situation does, however, emphasise an important fact. As Britain's railways reached their supremacy in an era when the country's economy was based on cheap and abundant coal, the skill and manufacturing resources of the traction section of the electrical industry found their main outlets in overseas countries, particularly those whose economies and natural resources obliged them to turn to electricity and oil as their principal motive power.

Thus from the earliest days of the electrical industry, electric traction has always formed an important section of its production, and some of the largest manufacturing companies in the industry to-day had electric tramway and railway business as their chief concern when they were started 50 years or more ago. Since then, railway electrification both at home and overseas has been pioneered by British engineers, and equipment they have supplied and installed is in operation to-day in all parts of the world.

The Conference and the specialised exhibition are attracting world-wide interest, and more than 200 railway engineers from the five continents are taking advantage of the opportunity to inspect this 'shop window' of the British traction industry. Equally as important will be the visits which are being arranged to the works of some of the leading manufacturers, where our visitors will be able to see for themselves the extent of the productive capacity of the industry. This has been steadily expanded during the past five years in preparation for the British Railways Modernisation Plan, and although the work involved in the latter is now approaching its peak, the electrical industry is also well able to provide for the export of complete locomotives of all types, as well as electrical equipment for rolling stock and power supplies.

While the emphasis at the October conference and exhibition and in the November issue of THE BEAMA JOURNAL will be on the 25 kV a c system of railway electrification, other sections of the traction field are covered in a number of special articles in the present issue, introduced by a survey of railway electrification history in the U K specially written for THE BEAMA JOURNAL by Mr S. B. Warder, the Chief Electrical Engineer of the British Transport Commission. Other aspects of the subject are also dealt with by authorities in their own fields of traction.

These special features and articles have been arranged with the co-operation of the Electric Traction Section of the B E A M A, which comprises the following member-firms:

Allen West & Co Ltd
Associated Electrical Industries Ltd
British Insulated Callender's Cables Ltd
Brush Electrical Engineering Co Ltd
Crompton Parkinson Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Hackbridge & Hewittic Electric Co Ltd
Pirelli-General Cables Works Ltd
Westinghouse Brake & Signal Co Ltd.

This Conference Year

Looking back on the three important conferences which have already made 1960 a notable year for the electrical industry, one persistent trend emerges again and again in all the proceedings. It might be shortly summed up in the phrase: 'More and more for less and less'.

To put this in its perspective, let us remark first that what we generally and loosely refer to as the 'electrical industry' is in practice a bimorphous structure made up of two independent but mutually indispensable entities —the supply industry and the manufacturing industry. Conferences such as the three reviewed in this issue—the British Electrical Power Convention, the World Power Conference and C I G R E—provide a common meeting point where representatives of both sections of 'the industry' can interchange ideas and experience in furtherance of their common objective.

World power requirements have steadily increased over the years; that they will go on increasing was accepted by all the speakers on this aspect of the subject, although the rate of increase and the factors which govern its forecasting may differ widely, as the discussion at the World Power Conference showed.

The significant point, however, was the repeated emphasis on the great contributions which British manufacturers have made through technological advances and improvements in manufacturing efficiency, resulting in reductions in the installed cost per unit of power from about £65 twelve years ago to about £39 now (according to Viscount Chandos in his Presidential Address to the B E P C); in gains in the real cost of manufacture averaging 2·5 per cent per annum exponentially (Messrs Booth and Dore of the C E G B in their paper to the W P C), and in the increase in plant thermal efficiencies, quoted by Sir Robertson King, Chairman of the Electricity Council, as 26·1 per cent last year, an expectation of 29·6 per cent in 1964/65 and rising to 36·5 per cent expected from the new 550 MW units at the Thorpe Marsh power station.

The economic advantages stemming from the increased (and still increasing) size of generating plant figured largely in these references, and once again the theme of 'more and more for less and less' was further developed by the Hon H. G. Nelson in his B E P C paper 'The New Horizon—Electrical Manufacture'.

Turning from conventional fuel generation to nuclear power generation, the theme becomes even more marked, and again, Britain's lead in this field was underlined in the discussions following Sir Christopher Hinton's paper to the W P C. The trend of specific plant costs is steadily downward; the net station efficiencies are rising with the new stations now projected, and the trend of generation cost per kWh from 1961 to 1966 in respect of gas cooled reactors is also steadily downward.

All these developments call for more and more from distribution systems and auxiliary equipment. Thus transmission voltages are going up. In Britain we already have the world's largest interconnected grid system operating at 132 kV, and within the last few years the 275 kV supergrid has come into being. The C E G B is now up-rating one section of the supergrid to 380 kV on an experimental basis and has ordered for the two ends of the line the two largest auto-transformers in Europe. If this development is as successful as it is expected to be, 380 kV will become the voltage of Britain's supergrid of the future.

Further aspects of this theme are brought to light by the impressions of the three conferences published in this issue. There is every indication that in the fields of generation, transmission and utilisation, the next decade will be of enormous significance for the electrical industry everywhere.

Development of International Standards

The importance of standards, both national and international, is now universally recognised, and nowhere more so than in the electrical manufacturing industry in view of its continuous and rapid development.

Recent events have underlined the international aspect and in particular the need for the United Kingdom to play an active part in the moves towards an alignment of electrical engineering standards among the Western European countries.

A policy statement issued recently by the Council of the B E A M A points out that in the last two years the European Economic Community has been working to achieve common standards throughout the 'Six' countries. An important development has now resulted from a meeting in Zürich of the Western European National Standards organisations. The six Common Market countries expressed their willingness to extend the collaboration so that the 'Six' and 'Seven' (E F T A) countries will in future co-operate on an equal footing. The 13 countries will now work as equal partners towards the alignment of Western European Standards and the maximum development of international standards through the International Standards Organisation (I S O), the International Electro-Technical Commission (I E C) and the International Commission on Rules for the Approval of Electrical Equipment (C E E).

The B E A M A Council considers it essential that the United Kingdom should play an active part in such developments and strongly supports any such efforts towards a greater degree of harmonisation in international standards and practices than has existed previously.

Through its close co-operation with the British Standards Institution and its participation in the work of the I S O, the I E C and the C E E, the B E A M A has for many years played a prominent part on behalf of the British electrical manufacturers in securing the establishment and recognition of standards, both nationally and internationally. In this latest move, it has again demonstrated the initiative of the electrical industry in fostering a development which, while of primary concern to itself, will in the long run benefit a much wider field.

Honours in the Electrical Industry

Among the honours conferred by Her Majesty the Queen in the Birthday Honours List are the following. On behalf of THE BEAMA JOURNAL and its readers, we offer our congratulations to:

Mr W. H. McFadzean, President of the Federation of British Industries; Vice-President of the British Electrical Power Convention, 1961; Chairman and Managing Director of British Insulated Callender's Cables Ltd, who becomes a Knight

Mr C. Robertson King, C B E, Chairman of the Electricity Council, who is raised to the rank of Knight Commander of the Order of the British Empire (K B E)

Mr T. E. Allibone, Director of the Research Laboratory of Associated Electrical Industries Ltd, who is appointed a Commander of the Order of the British Empire (C B E)

Mr L. F. Broadway, Head of the Research Laboratories of Electric & Musical Industries Ltd, and

Mr R. J. Clayton, Manager of the Applied Electronic Laboratories, General Electric Co Ltd, who are both appointed Officers of the Order of the British Empire (O B E).

Railway Electrification in Great Britain

S. B. Warder, MIMechE, MIEE*

THIS article is written as a prelude to the Conference on a c railway electrification which is to take place in this country in October. A subsequent article will appear in the November issue of THE BEAMA JOURNAL which will deal with the papers presented to that conference, giving some account of the potential future of a c electrification and what it will entail for all those associated in its development—whether as manufacturer, supply authority, or user.

This country, which produced Michael Faraday, has contributed much to the science of electrical engineering, but it is singularly odd that in this twentieth century, when electricity is demanded for every domestic or industrial application, its use for rail traction seems strangely denied. There are many reasons why this is so, and these need not be discussed here. Suffice it to say that the battles have been long and bitter, and they are best forgotten.

Historical Review

Historically, railway electrification can be considered in three phases.

PHASE 1. (1890-1916)

This period—when labour and coal were cheap and plentiful—saw the development of the steam locomotive to its greatest glory. In other countries where coal had to be imported and where hydro-electric power was available, electrification suited the national economy.

The first important application of electricity was to London's Underground Railways, where steam operation on the Metropolitan and District lines was intolerable.

In the years preceding the first world war the main line railway companies interested themselves in the electrification of suburban lines with low voltage conductor rails. This was the beginning of the present Southern Region electrified system.

The d c series-connected motor had ideal characteristics for the variable speed conditions necessitated for propelling trains, and generating stations in the early years supplied direct current. At the turn of the century the country's electricity supply was beginning to assume its present form as turboalternators were brought into use for the generation of alternating current.

For some years frequency was not standardised, and it was not until 1926 that Parliament took the decision which eventually led to the adoption of a 50 c/s standard frequency throughout the country.

Early rotary converters necessary to convert a c to d c for traction purposes required a c at a lower frequency for satisfactory performance. Consequently, the railways built their own power stations or used frequency changers to provide a low frequency current, generally at 25 c/s for conversion to direct current.

* Chief Electrical Engineer, British Transport Commission

While rail electrification in this country started with suburban systems, with a c/d c conversion at lineside substations making 600 V d c available through a third rail, practice on the continent, where the application has been for longer distance routes, used a higher voltage a c taken direct to the train and suitably transformed to permit the use of single phase series motors fitted with commutators for speed control. It was, however, necessary in such cases to use a low frequency of $16\frac{2}{3}$ c/s instead of the normal industrial frequency of 50 c/s. This was no great disadvantage at the time because the great continental countries of Sweden, Germany, Switzerland, and even France, were able to construct large water power stations exclusively for their own use.

It was soon evident that the successful application of direct current to main line routes required a higher voltage than could be carried by conductor rails. Thus, overhead systems were developed using 1 500 V and later 3 000 V, and the corresponding a c voltages at low frequency were between 6 and 15 kV.

PHASE 2. (1919-1939)

With the aftermath of the war and the growth of road competition, earlier hopes for widespread electrification in Britain were not realised, but great progress was achieved by the Southern Railway in its suburban and country electrification. It is worth recording that the extension of the third rail system beyond the normally accepted boundary of a suburban network was entirely the conception of Mr Alfred Raworth, the Company's Chief Electrical Engineer, who had the courage to apply for the first time on a main line railway the mercury arc rectifier supplied from the national supply system.

New electric stock for the Southern Region's recently-extended Kent Coast system

Other contributory developments to the successful electrification to the coast towns included remote supervisory control permitting the use of single unit unattended substations spaced 3·5 miles (5·6 km) apart, linked together by a 33 kV continuous ring main 50 c/s supply fed from the national grid at strategic points, as necessary.

It should be emphasised that these developments were not accidents, but were deliberately conceived to meet a

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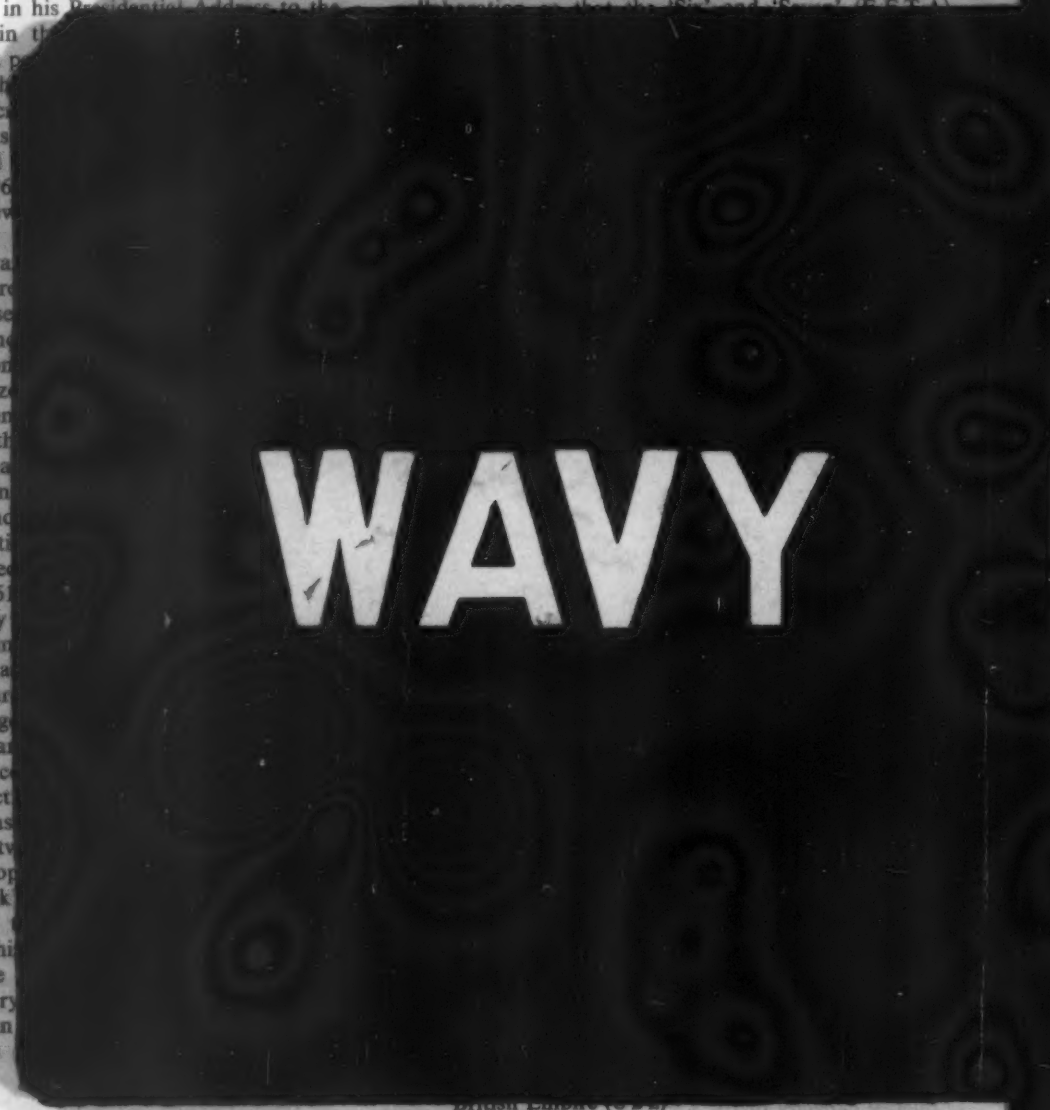

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It should be emphasised that these developments were not accidents, but were deliberately conceived to meet a

specific demand by railway electrical engineers who were aware of the benefits which could be conferred on railway operators from the application of their art.

The second world war brought electrification to a stop before the Southern Railway had time to complete the extension of the third rail system to its natural limit, but even so it was the largest system of its kind in the world, and statistically the figures are quite staggering. It has achieved a high standard of reliability, and its success is responsible for the vast dormitory area stretching south of the Thames on a radius of 30 miles (48 km).

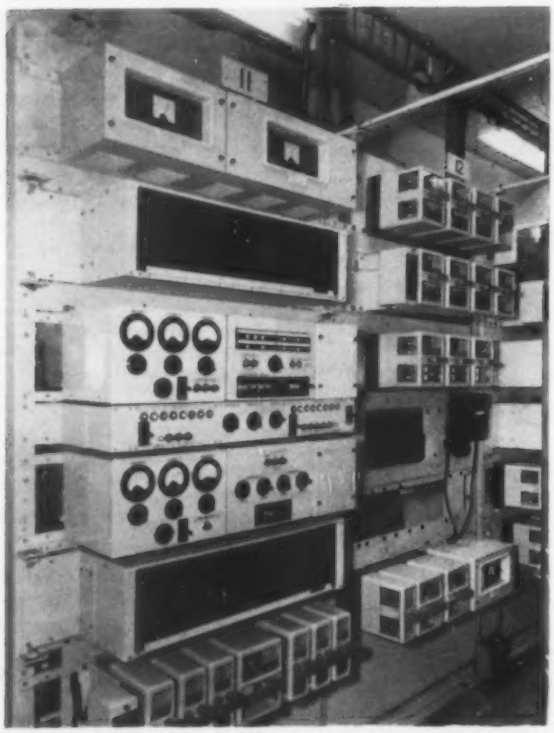
The architects of this great enterprise were three men whose achievements have, as yet, been insufficiently recognised. They were Sir Herbert Walker, General Manager; Mr E C Cox, Traffic Manager; and Mr Alfred Raworth, Chief Electrical Engineer.

The system has often been criticised, particularly for extensions beyond the suburban limits. It is basically a system which should be fenced in, because of the electrocution risk, and the gaps in the conductor rails make locomotive operation more difficult. The large currents now required for the peak hour 12-car train services are on the tolerable limit, and there have been difficulties with icing of the conductor rail in the winter in the country areas.

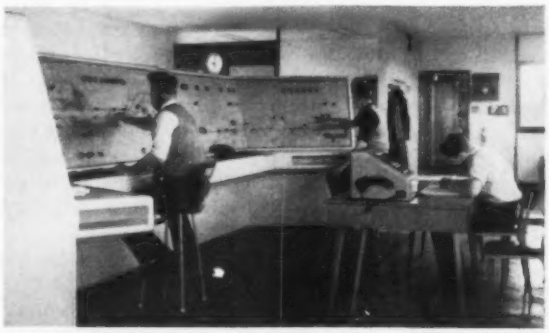
The third rail system was universally adopted when the Southern Railway was created in 1923 with the amalgamation of three different private railway companies, all using or contemplating different systems.

The then London, Brighton and South Coast Railway had to scrap their 6·6 kV 25 c/s overhead system, (*a*) because there was less of it than there was of third rail, and (*b*) it had not reached that stage of perfection which could (as is now possible) show outstanding technical merit.

Looking back now, it could be argued that it was a wrong decision; it was a decision of expediency, and how often decisions on grounds of expediency turn out to be wrong!



In the new Sittingbourne, Kent, signal box, these relays dispense with lever frames



The control panel in the Sittingbourne signal box

Almost all the objections to the third rail system mentioned above could be disposed of by protecting the conductor rail and arranging it for side contact, but the problems of carrying out the alteration while maintaining the service make it impracticable of achievement, so another fundamental rule of electrification has to be recorded: 'An electrification system cannot readily be changed if it is of any magnitude'.

There have been few instances where changes of system have been pursued by railway administrations, but there are many cases where different systems have existed side by side in the same country, and the reason for the difference has usually been due to the developing techniques which have occurred at regular intervals as greater knowledge has been acquired and applied. Thus the increase in d c voltages to 1 500 and 3 000 and the variety of low frequency a c systems, all of which have had their special application and advocates.

This period has variously been described as the 'Battle of the Systems'. To resolve this, so far as this country was concerned, various committees up to 1939 have reported that the proper system for the United Kingdom was 1 500 V d c, and this has been the position until the third phase, now to be discussed.

PHASE 3. (1945-1951)

Following the end of World War II it was decided to complete two 1 500 V d c schemes authorised and started before 1939: the Liverpool Street to Shenfield, and the Manchester-Sheffield-Wath lines, but these schemes before completion were severely affected by the economies enforced by the aftermath of the war and the subsequent political upheaval of nationalisation.

It was also decided to set up another committee to review the question of system, and in 1951 the Commission accepted that committee's recommendation that the standard system should continue to be 1 500 V d c, except for an area earmarked for extension of the third rail system of the former Southern Railway.

Thus, over a period of 25 years, three reports have been

made in Great Britain recommending the same system. Yet, because the recommendations have not been implemented, they have been overtaken by the march of science and another review has had to be undertaken.

It should perhaps be mentioned that the 1951 Report accurately reflected the experience of the period, namely: that there was a growing expansion of the 3 000 V d c system, and that the 50 c/s a c system at 20 kV showed promise. The 3 000 V system also proved to be the cheapest in the comparative estimates but was thought to afford more complications for inter-running with the 750 V third rail system. However, it was mainly because it was thought that only heavily loaded lines were likely to be electrified for many years to come that the Report recommended 1 500 V d c as a standard.

1951-1955: Five critical years

When railway history comes to be written it may well be found that the period 1951-55 was the most critical of all for this country, as indeed it has been in many other countries.

It covered the most difficult period of political uncertainty following nationalisation, economic crises, and the necessity to replace steam motive power. The success of diesel traction in the U S A added further complications, since the electric traction engineer, having assisted in putting the diesel engine on the railroad, now found a serious competitor to straight electrification. The case for financial justification had therefore to be started all over again against a more formidable opponent than steam. The rise in costs of material and labour during this inflationary period completely destroyed all previous comparative studies and it quickly became evident that new techniques were required with the objective of cheapening the cost of electrification if it were to remain a serious challenger in the field of rail traction.

This was recognised equally in France, where the S N C F operated a large and successful 15 000 V d c system from Paris to the south and south-west of France. It had become too expensive, and rather than change to 3 000 V d c as in Italy, or 1 500 V a c low frequency as in Germany and Switzerland, they extended previous German experiments with 20 kV 50 c/s.

British Railways also started experimenting by adapting

Electronic equipment in the Sittingbourne signal box for remote control of the Sheerness branch line

the Lancaster-Morecambe-Heysham line, previously operated at 6·6 kV 25 c/s, and ran multiple unit trains fitted with mercury arc rectifiers and d c traction motors on a 50 c/s supply. The first train in the world to operate with semi-conductor rectifiers ran on this line.*

The Continental boat train to Parkeston Quay from Liverpool on the Manchester-Sheffield electrified line

It is important to remember these facts, since it has been written and said in a number of places that the decision to adopt the 50 c/s system by Great Britain was merely copying the S N C F example. The record shows that British Railways started their pilot scheme before knowing of the success subsequently achieved by their French railway cousins. True they have taken longer, but that has been due to circumstances over which the technical departments concerned had no control.

During this period no firm decision had been reached as to what, where, and how steam traction was to be replaced, and this was first foreshadowed by the publication of the £1,500 m Modernisation Plan in December, 1954.

The plan provided for a great supersession of steam, but while it was accepted in principle that for the main routes of British Railways electric traction was the ideal method to be employed, a considerable engineering effort was necessary on track works, signalling and telecommunications.

It was evident that the electrification programme was essentially of a long term character, so that in order to introduce more immediate benefits, a complementary diesel traction programme was simultaneously initiated. In other words, it was decided that there was room for two forms of traction, each being applied in the appropriate conditions, on the grounds that considerable scope existed for either system.

The estimates for electrification covered by the Modernisation Plan were based on the 1 500 V d c system, but in view of the importance of the developments which had taken place in the techniques of a c electrification as demonstrated by the experiments mentioned above, the Commission recognised the possibility that its scope for further improvement would be greater than appeared likely with the systems already established in Britain. Instructions were therefore given for the survey of a typical main line and the formulation of estimates of the cost of construction, equipment and operation for electrification by both the 1 500 V d c and the 25 kV 50 c/s a c systems.

*THE BEAMA JOURNAL, 65, No 4, p 151

The Choice of System

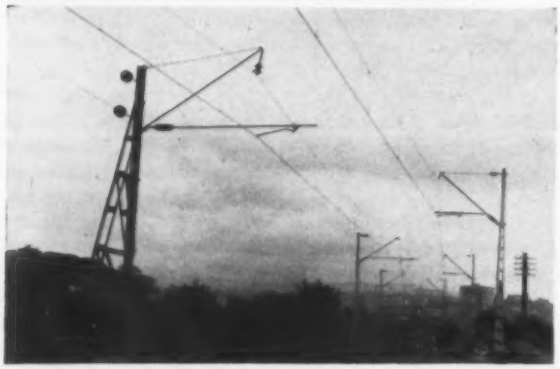
By 1954 it had become internationally agreed that the 50 c/s system employed the cheapest fixed equipment and that it was the ideal system where the traffic was light or infrequent. It was not so evident that the same conclusion would apply for heavily loaded lines or where the electrical clearances required were very costly to obtain, because it was thought by many that the savings to be derived from the cheaper fixed equipment would be absorbed—not only in obtaining clearance, but by the higher cost of a c electric tractors.

Subsequently, the S N C F demonstrated the superiority of the a c locomotive, ton for ton, over its d c counterpart by the ability of the former with its traction motors permanently connected in parallel to haul loads 60 per cent in excess of loads permissible for the equivalent d c locomotive, where the motors have perforce to be arranged in series/series-parallel groupings.

The question then for Great Britain was whether a better quality of motive power could be provided with an a c system operating from the national grid under British conditions. This system should utilise a voltage high enough to obtain a greater efficiency and security of power supply than was possible with d c of any voltage.

If these two basic conditions could be shown to be attainable at the same, or at a lower, first and annual cost than those of the d c system, there would be little argument which system was the best for British Railways.

Of course, the existing systems were giving a good account of themselves, and it would have been very convenient to continue with the 1 500 V d c system, since it presented few technical problems to the railway engineers or to industry, and offered the advantage of continuity of practice and manufacture. The a c system, on the contrary, posed greater technical problems and demanded the rapid development of new designs of fixed equipment and rolling stock. Further, there was the desirability of converting existing d c installations to the a c system.



A view of the up-to-date light single-track hinged cantilever construction for the catenary equipment on the Lancaster-Morecambe-Heysham line

But another consideration had to be taken into account. This was the long term view of the prospect of great economies coming from the wider scope for technical progress and the risk of being isolated from enjoying those possibilities in this country, to say nothing of depriving our manufacturing industry of the ability to participate in the vast expansion of an overseas market in a c traction that appeared more than likely to develop.

The study was made, and with the results of this study in their possession the British Transport Commission decided to depart from the electrification systems hitherto used in this country and to adopt as a standard the 25 kV 50 c/s system.

This was in 1955, since when a gathering momentum has been developing as all sections of industry have been designing, manufacturing and proving the equipment ordered in quantities without parallel in railway history.

Simultaneously it has been a major issue for the civil and signalling engineers, who have an immense part to play in bringing the railway track into a condition capable of operating at high speeds the new and more heavily loaded electric trains of the future.

Special Features of the A C System

Features of particular interest to engineers are the methods that have been employed to overcome the peculiarly British difficulties of clearance arising from the restricted structure gauge and the hundreds of bridges. The development of a two-voltage system in this connection, where the changeover from 25 kV to 6·25 kV is operated automatically without the assistance of the driver, has been particularly successful. Considerable thought has also been applied to the question of restricting inductive effects from the a c overhead line to paralleling telecommunication and signalling cables.

No one article can adequately describe these matters, and because of the immensity of the operation and its world wide importance, it has been decided to hold an Electrification Conference in London in October next to present the full story.

It is thought that by this means a comprehensive picture can be given, with practical demonstrations of the first equipments built, even before some of them have entered service. It will be many years before all the lines proposed for electrification are completed, and much of the equipment now coming into service will be outmoded by the improved designs which are already on the drawing boards as a result of the experience so far gained during the past year. Indeed, the technical developments foreshadowed when the Commission took their decision are already far exceeding expectations.

Forty-one papers are being prepared for the Conference in order that all aspects of the work can be covered, and all will be available for discussion. The time available, however, will only permit eleven of the papers to be actually read.

British engineers engaged in railway engineering, whether in design, manufacture or operation, will have every justification to be proud of the achievements of the last five years, and this account has been written with the purpose of describing some of the milestones of progress as an introduction to this important conference. Looking back it can be seen that all the developments described have a logical justification.

The new developments should enable this country to recapture its former predominance in the railway world.

The 'Midland Pullman'

BRITAIN'S NEWEST HIGH SPEED LUXURY DIESEL-ELECTRIC TRAINS

ONE of the important features included in the British Railways Modernisation Plan was the provision of new high speed luxury diesel-electric trains to operate between some of the principal cities in Britain.

This project was initiated at the end of 1956 and orders were placed early in 1957 for two 6-car and three 8-car trains to an entirely new specification. At the beginning of July this year the first two trains went into regular service between London and Manchester—183 miles (324 km), and London and Leicester—99 miles (159 km), to be followed shortly afterwards (probably in the autumn) by the three 8-car trains between London and Bristol—118 miles (191 km), and from London to Birmingham—110 miles (177 km) and Wolverhampton—123 miles (198 km).

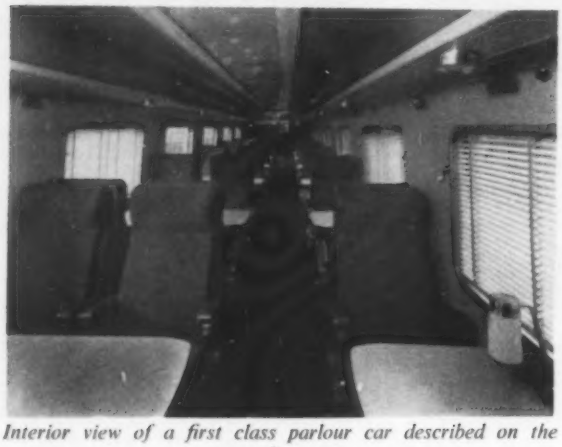
The 6-car trains carry first class passengers only; the 8-car trains have both first and second class accomodation. They are all unique in British railway history and introduce an entirely new conception of high speed main line railway travel with an exceptional degree of comfort, smoothness and silence. They are the first trains in Britain to be fully air-conditioned with controlled temperature and humidity, and particular care has been given in their design to the reduction of noise. The passenger accommodation is in enclosed saloons, the vehicles are heavily insulated against sound and heat, the windows are double glazed and have fully adjustable venetian blinds between the outer and inner panes of glass. Even the floors of the vehicles are fully suspended and insulated.

Each six-car train consists of two motor cars (the leading vehicles at either end), housing the two main diesel engines and electric generators, driving compartments, and saloons for 12 passengers; two kitchen cars which include non-smoking saloons for 18 passengers; and two parlour cars each seating 36 passengers. The total accommodation of the six-car train will be 132 first class passengers. The eight-car trains have additional seating in the motor cars and in two more parlour cars for second class passengers, giving a total capacity of 108 first class and 120 second class seats. The seating is all of the arm-chair type with foam rubber upholstery and in the first class cars the seats are also individually adjustable from upright to reclining positions.

Warm white fluorescent lighting concealed by opal diffuser panels provides the principal illumination throughout the passenger accommodation, supplemented by individual table lamps. In each saloon the main fluorescent lighting is by twin tubes placed end-to-end along the centre of the ceiling and covered by diffusion panels which, when illuminated, give an impression of a continuous panel of light running the length of the saloon. The inward flow of air from the air-conditioning plant in each vehicle is dispersed through ducts and outlets which are above, and concealed by, the central lighting panel. Additional illumination is provided by tungsten lamps fitted in the luggage racks above each table.

The air-tight and draught-proof passenger access gangways between the cars are of an entirely new design

and are far wider than usual. They are mounted on pivots at the ends of each car and, when joined together, form semi-floating units between pairs of cars, providing a level platform free from the oscillation associated with ordinary gangways. Rubber seals cover the outsides of the gangways and prevent draughts and loss of efficiency in the air-conditioning of the train.



Interior view of a first class parlour car described on the preceding page

The toilets are equipped with such features as towel dispensers and hygienic spray washing facilities which give an automatically timed flow of water at a temperature which can be selected to suit individual needs and is automatically maintained until the timed flow ceases.

In the kitchen cars, the kitchen and separate pantry accommodation has been designed with particular attention to hygiene and proper storage of food and drink. The walls are lined with an easy-to-clean plastic finish in pearl grey, the ceilings are matt white, and the floors are of red composition material. Four extractor fans are fitted in the roof of each kitchen space, two of them immediately above the fume chamber over the gas cooking range with its large grill. All the kitchen utensils, working surfaces and the sterilising and all-purpose sinks are of stainless steel. Other features include a constant boiling water supply and both deep-freeze and normal domestic refrigeration.

A public address system is installed throughout the train, through which the guard can keep passengers informed of the progress of their journey, and the guard and driver are linked by a Loudaphone installation.

Power equipment for the new trains was supplied by the General Electric Co Ltd of England, comprising diesel engines, generators, traction motors and spring drives for installation in the Pullman rolling stock which was designed and built by the Metropolitan-Cammell Carriage and Wagon Co Ltd. The diesel engines, cooling groups and engine accessories were supplied by the North British Locomotive Co Ltd of Glasgow as sub-contractors to the G E C.

The equipments are designed for a maximum service speed of 90 mile/h (145 km/h).

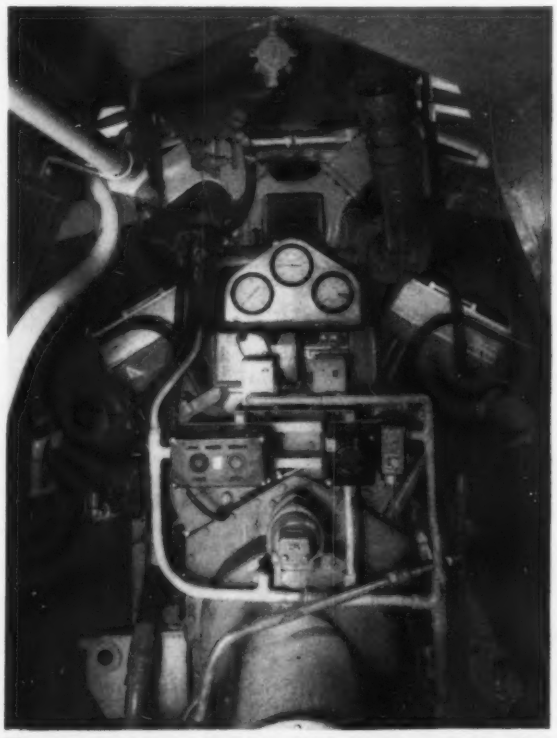
Both the 8-car and 6-car trains have a power car and driving cab at each end, the traction equipment in both cars being controlled simultaneously from either cab over a control line running through the train. At each end of a train formation there are two traction motors in the inner bogie of the power car and two in the adjacent bogie of the car coupled next to it, making 8 motors in a train of either 6 or 8 cars.

Power Car Equipment

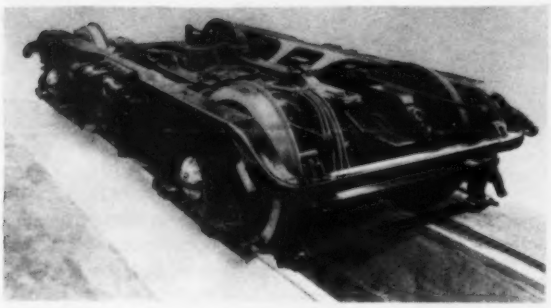
Immediately behind the cab in the power car is the Serck radiator unit, a built-up structure providing a central tunnel-shaped passageway with side ducts housing the cooling elements for the engine water and the lubricating oil heat exchanger. At the top of the unit is the header tank and the housing for the 45 in (114 cm) diameter fan, which is driven at variable speed by a Serck/Behr hydrostatic drive.

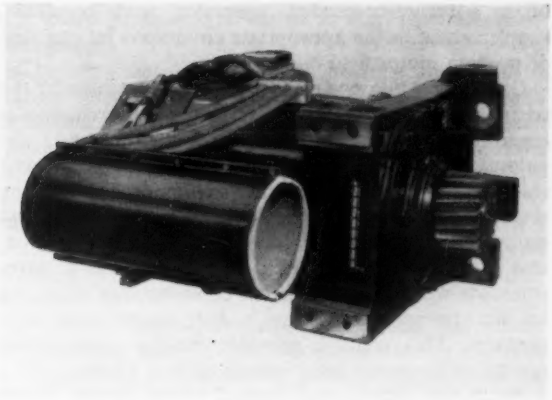
Beyond the radiator unit is the engine-generator set, consisting of a N B L/M A N 12-cylinder V-engine direct-coupled to a G E C main generator with overhung auxiliary generator, the whole set being mounted on anti-vibration mountings. A bulkhead separates the engine from the generators. A main traction control switchgear cabinet stands against the main end wall of the generator compartment. Traction motor field divert resistors are mounted on top of the cabinet, and the generator automatic field regulator resistances are in the compartment roof. A small cabinet containing auxiliary switchgear is accommodated in a short passageway at the other side of the compartment. The engine generator set is extremely light for the power output and makes possible the very high performance of the train sets.

The N B L/M A N diesel engine, with twelve cylinders of 180 mm bore by 210 mm stroke, is fitted with a Napier exhaust gas turboblower giving a boost pressure



The main engine compartment of the power car as seen from the doorway to the driver's cab





(Above). *One of the motor bogies and* (right) *one of the traction motors described on this page*

of 10·4 lb/in² (900 g/cm²) and has a 12-hours rating of 1 000 h p at 1 500 rev/min. Engine fuel is pumped from a main supply tank to the service tank by a belt-driven Dowty pump of 90 gal (409 l)/hr capacity. The lubrication system is pressure-primed by a Mirrlees pump driven by a G E C motor. An Ardleigh governor is fitted.

The Generators

The main generator is a six-pole machine with a coupling flange at the driving end through which the armature is solidly bolted to the engine crankshaft flange. An extension to the main generator shaft carries the auxiliary generator, the weight of the two armatures being carried partly by the self-aligning parallel roller bearing between them in the generator end-shields, and partly by the engine outboard crankshaft bearing.

A fan mounted on the driving end of the main generator armature draws ventilating air partly through the auxiliary generator and partly through protected vents in the bearing housing; it passes in parallel paths through the armature cores and over the periphery of the armature and field coil surfaces, and is exhausted into the engine compartment.

The main generator armature winding is of duplex lapform, which is considered to give the best commutation conditions for this particular application because it results in moderate values of both reactance voltage and voltage between commutator segments. Field windings of this machine follow conventional traction practice, consisting of separately-excited and self-excited main fields with a series decompounding winding which also forms part of the series excitation for motoring the generator when starting the diesel engine. Continuous ratings of both generators are as follows:

Main Generator

1 700 A, 383 V, 1 500 rev/min, 650 kW.
1 250 A, 523 V, 1 500 rev/min, 650 kW.

Auxiliary Generator

91 A, 110 V, 650/1 500 rev/min, 10 kW.

The voltage output of the auxiliary machine is controlled over the whole engine speed range by a Newton carbon pile voltage regulator. This generator supplies excitation for the main generator separately-excited field and current for battery-charging, control circuits, compressor and oil priming pump motors and cab heating. Cab lights and marker lights are supplied at 24 V d c via transformer-rectifier units from diesel-driven alternators installed in the trains for air-conditioning, train fluorescent lighting and other auxiliary services. A 110 V cooker with 3-heat switch is provided in each cab.

Traction Motors and Drives

These trains are the first diesel units on British Railways to have fully springborne traction motors.

Two flanges are provided on each motor through which it is bolted to the vertical face of the bogie transom. With this arrangement the gearwheel cannot be mounted direct on the axle in the usual way because the distance between the motor pinion and gearwheel centres varies with the action of the bogie springs. This relative movement is allowed for by the Brown-Boveri spring drive, which consists of a short quill shaft clamped to the motor frame at the driving side; the driving axle passes through the quill—which is shaped to allow clearance for axle movements, particularly vertically—and a gearwheel rotating in roller bearings on the quill, so that the distance between the motor pinion and gearwheel centres is fixed.

The necessary flexible coupling between the gearwheel and the driving axle is provided by a spider pressed on to the wheel hub, with its arms projecting inside the gearwheel. Torque is transmitted from the gearwheel to the spider through coil springs inside the gearwheel which bear at one end against the gearwheel spokes and at the other end against the spider arms, the contact at both ends being made through spring cups.

The traction motors are four-pole, self-ventilating machines with a rating of 425 A, 383 V, 199 h p at 1 360 rev/min. The gear ratio is 19/67. The two motors in each power bogie are in parallel. Those in the second vehicle from each end of a train are supplied through power cables from the adjacent power car. Their field divert resistors are mounted on top of the power car traction switchgear cabinet, and their value is adjusted to allow for the voltage drop in the cable connections.

Control Scheme

Basically, the method of control consists of selecting eight different engine speeds between idling and 1 500 rev/min, at each of which the corresponding output is available over a wide range of train speeds by the action

of a governor-controlled generator field regulator, supplemented in the appropriate conditions by one step of traction motor field-diversion.

On the first two power positions of the controller the engine runs at idling speed and generator excitation is controlled by fixed resistance steps. On notch 3 the automatic regulator becomes operative with the engine still at idling speed and remains in action on the remaining seven notches, on each of which the engine speed and output are increased in graded steps. Engine speed control is effected by the action on the governor of three solenoids which lift in different combinations according to the energisation through the master controller contacts. This method provides exactly synchronised control of the power units at both ends of a train.

As in the Type 1 and Type 2 North British diesel-electric locomotives with G E C power equipments, the automatic load regulator takes the form of an oil-operated vane motor driving rotatable brushgear round a fixed commutator, the segments of which are connected to the regulating resistances in the main generator separately-excited field circuit.

When the generator load varies with the track conditions it tends to alter the speed of the diesel engine; this causes movement of the governor to maintain constant speed conditions by admitting oil to the vane motor so that it rotates in the direction necessary to decrease or increase the generator excitation.

Field-weakening of the traction motors takes place in the appropriate conditions under the control of a transition relay in the generator field circuit. When this operates, the load regulator moves back towards minimum excitation and the weak-field contactors close when the generator voltage and current have been adjusted to the correct values. Full-field is restored automatically when appropriate by transition current relays in one motor circuit of each power unit.

A current limit relay arrests the increase of generator excitation by the automatic load regulator during acceleration of the train if the current exceeds a predetermined setting. When the current falls with rising train speed to the relay drop-out value, the increase of excitation is resumed under the normal control of the load regulator. The relay thus ensures that damaging wheel slip is avoided when accelerating under poor adhesion conditions.

Interior view of the driver's cab

A general view of the control equipment in the power car

In addition to the power handle, the master controller has a selector handle with 'forward', 'engine start', 'off' and 'reverse' positions and the usual interlocks are provided. All power contactors are electro-pneumatic. A master motor cut-out switch with cam-operated contacts is located at the side of the traction switchgear cabinet and enables the traction motors to be isolated singly or altogether.

Warning lamps in the generator compartment brighten to indicate low water level, high water temperature, low oil pressure, overload and earth fault. The engine is slowed automatically to idling in the event of high water temperature, overload or earth fault, the last-named also disconnecting the main generator separately-excited field from the auxiliary supply and introducing a discharge resistance by means of a changeover contactor.

Two indicator lamps on the driver's instrument panel brighten to show 'engine stopped' or a general alarm. They operate in case of trouble in either power car, the fault being localised by inspection of the individual power car fault panels.

Eight power cables, connected between the power car and auxiliary power cars at each end of the train, supply the traction motors on the auxiliary power car. The 36-line control cable running throughout each train is conveyed between coaches by jumpers and receptacles

with butt contacts; these avoid the difficulties experienced with plug and socket types when plugs become misaligned.

The trains are equipped with the latest Westinghouse two-stage electro-pneumatic brake system which enables them to be stopped rapidly and smoothly from high speed.

The electro-pneumatic brake provides electrical control of the pneumatic brake by solenoid operated valves on every car connected by train wire and energised from switches operated by the driver's brake controller handle. This system ensures that the brake responds instantaneously and, by virtue of operating simultaneously throughout the train, it ensures balanced braking on all coaches, with enhanced comfort for the passengers. This brake is similar to that already in use on many electric trains of British Railways and the London Underground.

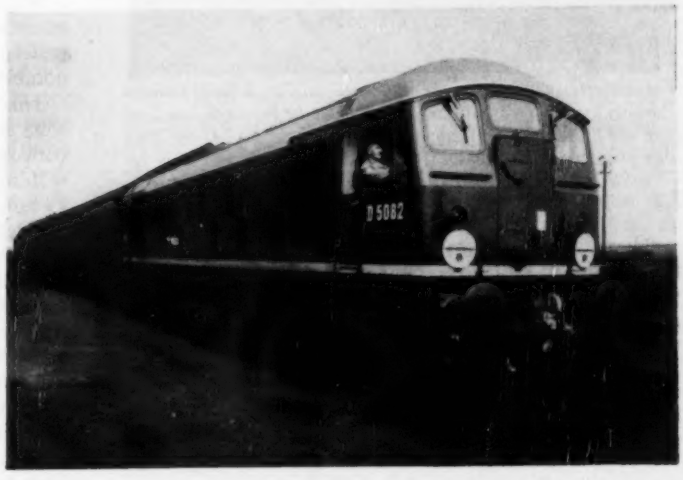
The standard Westinghouse automatic air brake is also embodied in the system as a standby service brake and is applied by appropriate movements of the single driver's brake controller handle. Furthermore, it will operate automatically on all cars if a train should break apart or if a guard or passenger wishes to stop the train in an emergency.

The two-stage, or high speed, brake is an automatic feature superimposed on the electro-pneumatic and automatic air brakes and permits retardation from a high speed to be maintained during braking at rates nearer the safe limit of wheel adhesion than would be possible with a single-stage brake. This is achieved by automatically increasing the brake force at high speeds and reducing it as the speed falls in order to avoid the liability to wheel skidding. As a result, the train can be stopped in a shorter distance.

All these diesel-electric *de luxe* trains have been designed and built by Metropolitan-Cammell Carriage & Wagon Company Limited, to the requirements of the British Transport Commission, under the general direction of the Chief Mechanical Engineer, in collaboration with the Chief Electrical Engineer and Chief Traffic Officer, respectively, of British Railways Central Staff, B.T.C., and The Pullman Car Company. The Chief Mechanical & Electrical Engineer, London Midland Region, was responsible for inspection during construction and for test running.

Brief Technical Details

Length of train (over buffers) { 6-car ..	409 ft 1 in (125 m
8-car ..	545 ft 1 in (166 m)
Length of vehicles (over body): { motor car	66 ft 5½ in (20·2 m)
other cars	65 ft. 6 ins (19·9 m)
Height from rail level to roof level	12 ft 4½ ins (3·76 m)
Width (at waist)	9 ft 0 ins (2·74 m)
Distance between bogie centres	46 ft 6 ins (14·2 m)
Distance between axle centres (motor and leading bogies)	9 ft 6 ins (2·89 m)
Distance between axle centres (trailer bogies)	8 ft 6 ins (2·59 m)
Wheel diameter (all wheels)	3 ft 6 ins (106·6cm)
Maximum service speed	90 m p h (145 km/h)
Weight of train in working order (6-car) ..	299 tons
Weight of train in working order (8-car) ..	364 tons



A British Railways Type 2 mixed traffic 1 160 hp diesel-electric locomotive equipped with A E I electric power equipment and Sulzer engines. In addition to 151 sets of equipment already being supplied, A E I have now received a further order for another 25 sets. The latter will be generally similar, but there is a notable difference in that the gear ratio has been lowered to raise the maximum speed from 75 to 90 mile/h (121 to 145 km/h). To accommodate extra horse-power, modified insulation has been incorporated in the traction motors and generators.

Electric Traction for City and Suburban Services

J. H. Cansdale, MIEE, MI Loco E*

THE first extensive use of electric power for traction purposes was on street tramways, and towards the end of the 19th century—at a time when steam had become firmly established on the railways—electrically operated cars began to replace the old horse-drawn vehicles on the roads of London and the major cities and towns throughout Britain. By 1915 the change-over in London was complete, and the last horse-drawn tram made its final journey on 30th May in that year.

Electric traction for rail vehicles was however a slower development, but the first application of electric motive power in this field came as a natural sequence to street electric traction. Britain can claim to have pioneered in this, as in so many other fields of electricity, by building the first underground electric railway in the world. This was the City and South London Railway, built in 1890. It operated, as its name implies, from King William Street, just north of the Thames in the City of London, to Stockwell, then a suburb in South London—a distance of 3·25 miles (5·2 km); its trains were drawn by separate locomotives of 100 h p; it ran throughout in a tunnel which was 87 ft (26·5 m) below the surface at its deepest part—and it made history!

This historic picture shows one of the original City & South London Railway locomotives, built in 1889-1890, at the Borough Junction. The old line to the City can be seen on the right. At the time this photograph was taken (1922) the locomotive had been rebuilt at the Stockwell Works with modified control gear

These two projects underlined vividly the great advantages of electric traction for city rail services, and further underground lines soon followed in London and other large cities, while some suburban railway services began to change from steam to electric power.

After the Central London Railway, two other lines—the Metropolitan Railway and the District Railway—were electrified. These were not strictly 'underground' railways, but ran partly on the surface and, in the city sections, in tunnels which had been built on the 'cut and cover' system. Initially they had operated with steam locomotives despite all their obvious disadvantages.

This line was followed in 1900 by the building of the Central London Railway, which ran for 5·75 miles (9·3 km) from the Bank (in the heart of the City of London) to Shepherd's Bush, at that time a suburb almost on the western edge of the metropolis. As a matter of interest, this line was popularly known for many years as the 'Twopenny Tube', as it was constructed entirely in a tubular tunnel and the charge for a journey of any distance was twopence.

By this time, electric traction was firmly established for city railways and London's underground system continues to lead the world. From its initial venture of 3·5 miles (5·6 km) of electrified railway in 1890, the system has been built up over the years until to-day the London Transport Executive operates a total of over 200 route miles (322 km) on which more than 1·5 million passengers travel daily from points up to 20 miles (32 km) away from the city centre.

Suburban Electrification Expands

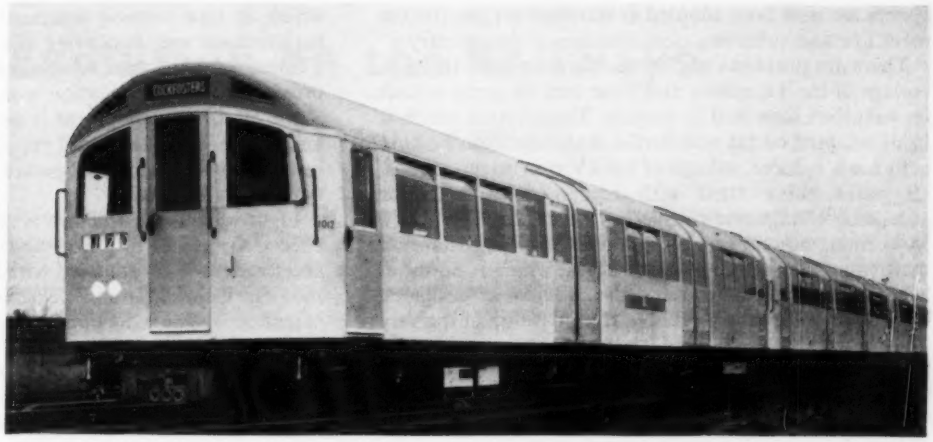
In addition to the London Transport routes, the electrified sections of the Southern Region of British Railways extend now to nearly 700 route miles (1125·8 km) south of London, covering practically the whole area between Margate on the east coast and Portsmouth on the south coast. This system, using the 660 V d c third rail system, began as several separate sections of purely suburban route, but it has in fact been extended to include certain main line routes on which express passenger trains now operate between London and many of the South coast resorts.

While its building and population density made it essential for London to put its city centre railways underground, different circumstances produced another notable pioneer effort elsewhere.

This was the Liverpool Overhead Railway, which in 1893 adopted electric traction on account of the fire risk with steam locomotives. Each bogie carriage was fitted with a 40 h p motor driving one axle; the cars weighed 19 tons loaded, and the trains consisted of two cars.

While London has by far the largest electric railway system of any of the world's capitals, there are other cities in Britain which also began to electrify their suburban lines before 1910, notably Liverpool, Manchester and Newcastle-upon-Tyne. Now, as part of the Modernisation Plan of British Railways, further suburban electrification is in hand, including additional routes out of London such as the Fenchurch Street–Southend line, the Glasgow suburban area, and some local lines south of Manchester which will form part of the Euston–Crewe main line electrification. All these will operate on the 25 kV a c 50 c/s single phase system.

* Sales Manager, Traction Division, Associated Electrical Industries Ltd



A view of one of the trains of London Transport's new 'silver' Tube stock described in this article—so called because unpainted aluminium is extensively used in the coach construction

The pattern of development in Great Britain has been closely followed in other countries. Most of the world's capital cities, such as New York, Moscow, Paris, and Rome (to mention only a few) have electric railways operating partly underground and partly on the surface. In Australia, Argentina, India, Brazil, South Africa, and Canada (again mentioning only a few of the countries concerned), their largest cities depend upon electric trains to move the bulk of the people between their homes and their places of work every day.

The increasing congestion on the roads and the waste of time involved for those who travel by private car is focusing attention more and more on the advantages of rail transport for all city travellers, particularly where heavy morning and evening peak traffic periods are involved. One single track of electric railway can transport about 40 000 persons an hour with speed and safety; a single lane of road transport can handle only about 2 000 persons an hour in private cars and this only if there is free movement without street congestion. There is no doubt whatever that electric trains have an essential part to play in any modern city, and wherever an intensive service is required—as in all large cities such as London—there is no possible alternative to the use of electric power.

The Multiple Unit Train

One of the outstanding features of electric traction as applied to city and suburban railways is the multiple unit train. This comprises a number of passenger coaches, some or all of which are fitted with driving motors, control being effected from one of the driver's compartments with which certain of the coaches are equipped. M U trains were first introduced into Britain on the Waterloo and City Railway in 1898, and since then such trains have invariably been used on electric railways of this type.

Multiple unit stock has a number of advantages over the locomotive-hauled train. The makeup of the train is very flexible and an 8-car train, for example, may comprise four 2-car units which can be made up into four different lengths of train, depending on the traffic requirements. The driving motors on such a train are disposed evenly throughout the train and consequently high rates of acceleration can be obtained, since a large proportion of the train weight can be utilised for adhesion. Furthermore, the acceleration rate remains uniform for any train makeup.

Maximum use can be made of platform length, since the whole train consists of passenger coaches, and turn-round is simple at terminal stations as the train can be driven equally well from either end. Train control wires with couplers between coaches enable all the operations of acceleration and braking to be controlled from one driving position for any length of train.

Early multiple unit motor coaches used part of the coach to house the control equipment, but it is now usual to mount all such equipment underneath the coach, thus releasing valuable additional space for passengers. Coaches may vary from the Tube rolling stock suitable for use in the 12-foot (3·66 m) diameter tunnels of London Transport to main line multiple unit coaches similar to normal surface stock and designed, in some cases, for express services as on the Southern Region of British Railways. On the Southern Region electrified routes, apart from a few special electric locomotives used chiefly for goods traffic, all passenger services are run by M U trains.

Traction Systems

In a city, it is seldom possible to provide any new railways except by going underground, and this may be done by tunnelling, as in London where the clay substrata are suitable for the purpose, or by 'cut and cover' methods as has been done in Toronto, where the rapid transit line runs under one of the main thoroughfares of the city. Restrictions of space make it necessary for most railways of this type to operate on the low voltage 600/660 V d c system, using an insulated conductor rail for the current supply, with either the running rails or a separate insulated rail for the return path.

Suburban lines can, and often do, operate as part of the larger electrified line, and there are typical examples of 1 500 V d c trains operating with an overhead conductor wire in the cities of Australia and India, and of 3 000 V d c trains in South Africa and Brazil; similarly, a c multiple unit trains operate in Sweden, Switzerland and other European countries, using their standard 15/16 kV $16\frac{2}{3}$ c/s a c single phase system; and in Great Britain and France, similar trains are in service on the latest 25 kV 50 c/s a c single phase system. This

system has now been adopted as standard for any further main line and suburban electrification in this country.

There are problems of clearance arising from the high voltage of the a c system and these may be quite serious on suburban lines and in tunnels. The solution which is being adopted on the new British Railways electrification is to use a reduced voltage of 6·6 kV over such sections, all trains being fitted with equipment suitable for automatic changeover to this lower voltage. The 25 kV M U trains now in service on British Railways have all their equipment mounted underneath, which is no mean achievement, bearing in mind the problem of designing high voltage apparatus suitable for mounting in the very limited space available under a standard railway coach.

The Future

The development of nuclear power, slow though it may seem to be, is a sure indication of the basic power supply of the future, which can only be electricity. Sixty years of electric traction on city and suburban railways have proved its supreme position in this field, and there is every indication that it will develop still further. The pattern of such development is likely to be on conventional lines on most railways where electric trains are already operating.

An interior view of the London Transport 'silver' Tube stock shown in the photograph on page 95

On the London Transport system, for example, improvements in various directions are being made with each batch of new rolling stock. From time to time minor improvements are introduced on the control equipment and motors in order to increase their life and reduce maintenance. Rubber bogie suspension is a feature which is now coming increasingly into use, reducing maintenance and improving the riding of the coaches. Fluorescent lighting is now usual on new stock and this provides better illumination with the use of less power. Static electronic equipment is now available for voltage and motor-generator speed regulation and for use as an inverter to enable battery power to maintain emergency fluorescent lighting.

Light-weight construction is always attractive since it effects economies in power and enables higher rates of acceleration to be obtained without having to use larger motors. Considerations of safety naturally limit the extent of weight reduction, though continuous improvement in materials and methods of construction are all tending towards lighter equipment and coaches. A considerable amount of aluminium is now being used for London Transport coach construction.

A recent interesting innovation is the use of a coach weighing device which automatically adjusts the accelerating and braking equipment on individual coaches so as to maintain the rate constant, irrespective of actual coach loading. Rheostatic braking is being used increasingly, and although it adds some weight and complication to the equipment it does effect reduction in brake shoe wear, and has the great advantage of reducing trouble caused by brake shoe dust. In some cases, the energy produced by rheostatic braking is used to assist in heating the coaches during cold weather.

Interesting Novelties

There are two developments which may affect the future of city and suburban electric trains, though at the moment they cannot be considered other than as interesting novelties. Rubber-tyred coaches such as those run by the Paris Métro offer the advantages of quieter running and higher accelerating and braking rates. Similar coaches are being considered for a new underground railway in Milan, but of a design which eliminates the need for running rails and therefore offers cheaper track construction. The higher tractive resistance of rubber tyres does however increase the power consumption, and it remains to be seen whether the advantages of this system outweigh the disadvantages.

The other novelty, though it should be more correctly considered as an old idea which is resurrected at intervals, is the monorail system. This has been suggested on various occasions in the past and it always arouses temporary enthusiasm as new variations are introduced on the old theme. So far, monorail systems have never gone beyond the scale of experimental sections, and though many places have investigated the idea, no actual complete installations have yet been made.

The future of the electric train is assured in so far as city and suburban travellers are concerned. They will never be able to look to road transport to meet their needs; they must depend increasingly on an efficient public transport system on rails. The modern electric railway is, and will continue to be, an essential part of any modern city, and Britain has an unrivalled experience in this field.

Evolution on the Railways

W. G. Jowett, B Sc (Eng), A M I E E *

Editor's Note. *This article, and the article by Mr. S. B. Warder on pages 85 to 89, approach the same subject from slightly different points of view: Mr Jowett from that of one of the leading manufacturers of electric and diesel-electric locomotives, and Mr Warder from that of the railway electrical engineer. It is inevitable that both articles should to some extent cover the same ground, but in other respects they are complementary. Between them they present a complete and authoritative survey of the progress of railway development in the U K, together with some indications of the achievements of the British electrical industry in this field.*

As Mr Warder points out in his article, the whole operation is too vast to be covered completely in one survey or even in one issue of the B E A M A Journal; further articles will therefore appear in our next issue.

Introduction

Railways were essentially a British invention, born early in the nineteenth century. Progress was rapid, and for the best part of 100 years steam traction had no rival. The competition which existed was simply that among the various steam locomotive builders and among the builders of those products associated with steam railways. The experience obtained in building and operating steam railways produced a breed of engineers of the highest calibre whose services were widely sought, whose advice was respected, and whose products were exported to all parts of the world. In this way, Britain made a major contribution to the world-wide development of railways.

For fifty years, steam provided the motive power for railways but the late nineteenth century saw the birth of electrical engineering and the internal combustion engine, both of which were to become competitors of steam traction.

Until the last quarter of the 19th century, all forms of street traction had been horse-drawn. This was followed by some unsuccessful efforts to introduce steam powered vehicles, but the evolution of electric traction soon superseded both these earlier forms. Its success was mainly due to the suitability and reliability of the d c series motor, and it was quite natural that, following such success, the railways should also explore the possibilities of electric traction for their own use.

Tramcar systems were invariably fed with direct current from small power stations which generated at low voltage, and largely because of this voltage limitation, the traction systems had also to be small, local and compact. D c is difficult to generate at high voltage, and there appeared therefore to be a limit to its development and application, particularly to railways. However, the advent of the a c generator (or alternator as it is now called), combined with the invention of the transformer, made possible the manufacture of much larger generating sets and the transformation of voltage, up or down as required, at high efficiency. And so a second alternative appeared in the railway electrification field.

After some experimentation the form of this rival became stabilised, with a single-phase supply at voltages of 6 kV to 15 kV transformed on the vehicle to a lower voltage and feeding a number of traction motors of the single-phase series commutator type. The frequency of industrial power distribution at this time was generally 25 c/s, because at this frequency flicker was hardly discernible on filament lamps and the series commutator motor was most difficult to design for higher frequencies. In any case, the a c series commutator motor was a machine much inferior to its d c counterpart.

The inventions of the rotary converter, which converted multiphase a c to d c, and later of the mercury-arc rectifier, advanced the claims of d c and the voltage of these systems increased to 1 500 V, and more recently to 3 000 V, which for technical reasons seems to represent the limit of economic development.

Electric traction engineers were thus faced with a difficult choice: they could choose the d c system with its supply limitations, or the a c system with its traction motor problems. The high cost of electrification was however the main restriction on its general application and use, and a continuous search for cheaper or alternative solutions was maintained.

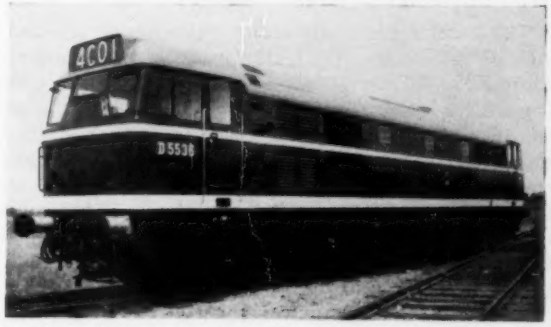


Fig 1. A Class 2 diesel-electric locomotive built by the Brush Electrical Engineering Co Ltd. Large numbers of these are being supplied to British Railways

Diesel Traction

An alternative solution appeared to be possible through the application of internal combustion engines to railway motive power. The early internal combustion engines were small and so, not unnaturally, were applied to private carriages, and later to commercial vehicles. The first World War accelerated their development and, with the improvements in the roads, petrol-engined vehicles were soon actively competing with the railways

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for suburban passenger and goods traffic. A few experimental equipments were built to try out petrol-engined rail vehicles, but these were on the whole unsuccessful because of the low powers attainable and because the pneumatic tyre, which provided cushioning of the drive between road wheels and engine, could not readily be applied to rail vehicles.

The efficiency of these engines was much higher than that of the steam engine, but the fuel was dangerous for railway use and was also relatively more expensive than coal.

Before the first World War, Dr Diesel suggested means for raising the efficiency of internal combustion engines. He built engines with high compression ratios, using the heat of compression to ignite the fuel. These early diesel engines were heavy and ran at low speed. They required complicated auxiliaries, particularly those required to inject vaporised fuel into the already compressed hot combustion air. In the late 1920's reliable direct injection metering pumps were developed which simplified the auxiliaries, and as a result speeds were raised and weights were reduced.

Fig 2. A Class 3 diesel-electric locomotive of 1 550 hp, with Crompton Parkinson electric transmission

The diesel engine itself cannot exert torque at standstill; in fact, at any given fuel injection, it is a constant-torque device. Therefore a torque-converting transmission (*e g* a multi-ratio gearbox, electric or hydraulic transmission) is required between the engine and the road wheels to give the required traction characteristic. D c machines, eminently suited to these requirements, were available for large powers and multi-ratio gearboxes and clutches for small powers. The Flying Hamburger railcars in Germany, and the Burlington Zephyrs in the USA, were typical pacemakers of this era (the 1930's).

However, still larger powers for the same weight were required if diesel locomotives were to become real competitors of steam, and the next major development was the advent of exhaust-gas pressure charging, which boosted engine powers up to 50 per cent without a material increase in weight. At this stage the diesel engine effectively entered the rail traction field.

Between the Wars

In Britain, the railways were feeling the effects of road competition, and in an effort to check the flow of traffic to the roads, the Railway Amalgamation of 1921/23 brought about the formation of four essentially non-competitive railway systems: the London Midland and Scottish Railway; the London and North-Eastern Railway; the Southern Railway; the Great Western Railway. The results of this have proved disappointing, and in an endeavour to improve railway operation, a committee was set up in 1927 to investigate the best technical basis for electrification.

The committee's report recommended electrification at 1 500 V d c, but little was done. Only the Southern Railway had a co-ordinated plan for the extension of electrification at 660 V d c on the third rail system. It is true that some electrification was carried out in some areas of the other railways, but these were mainly small suburban schemes where steam traction was incapable of handling the traffic offered.

A second committee was set up in 1929 to investigate and report on main-line electrification, and again the recommendation was for electrification at 1 500 V d c. About this time, some experimentation was also carried out on diesels, but they only became really established for shunting.

Just before the outbreak of the second World War, approximately equal mileages of d c and a c electrification had been carried out in various parts of the world. Continental practice, in the main, favoured the a c system (Switzerland, Sweden, Germany, Austria), and British manufacturers favoured the d c system. In spite of the lack of a "shop window" at home, extensive electrification works were carried out overseas by British manufacturers, for example, in South Africa, Australia, Brazil, Denmark, France, Japan, India.

The second World War put an end, temporarily, to railway development except in the U S A, where mass-produced diesel-electric locos were built in thousands to try to satisfy the transportation requirements of a nation not under enemy fire, but supplying the needs of her allies.

By 1945, after the second World War, the railways in Britain were in a poor state; they were overworked, under-maintained, and starved of capital. These were the conditions that existed when the railways were nationalised and a new body—the British Transport Commission—was brought into being to operate a single system: British Railways.

In the U S A the steam locomotive was fast disappearing; electrification was considered to be too expensive owing to the comparatively light loading of many of their routes, and diesel motive power was championed as the only salvation for their railways.

In those parts of Europe which had not been devastated by the war, electrification was proceeding according to the pre-war plans, using the $16\frac{2}{3}$ c/s a c system. Only on the Hollenthal Railway in Germany had an attempt been made to apply 50 c/s single-phase power to railway electrification.

Railway engineers realised, however, that if power from the existing industrial networks could be used for traction purposes without conversion, the cost of electrification could be substantially reduced, and that diesel power was not necessarily the answer everywhere, even if it was right for the requirements of the American railroads.

France had occupied the part of Germany which contained the Hollenthal Railway and French railway engineers investigated the problem afresh, even though the Germans had decided against industrial frequency

traction. The French engineers disagreed with this decision and equipped a trial line of their own near Annecy. They claimed to have solved successfully the problem of producing a 50 c/s single-phase commutator motor, and railway engineers from all over the world were invited to come and see for themselves.

Following the trials at Annecy the French engineers decided to break with their established system—1 500 V d c—and to electrify the North-eastern area of France direct from the industrial power network at 25 kV, 50 c/s, single-phase. It had been expected that the locomotives would be equipped with single-phase commutator motors, but a mixture of types was ordered: some single-phase to d c with rotary converters; some single-phase variable frequency with rotary converters, and some three-phase induction type traction motors—a few with a c commutator motors and a very small number with rectifiers and d c traction motors.

British Railways now called for a third investigation and the committee reported in 1951 in favour of electrification at 1 500 V d c where the traffic was dense enough to pay for it, and recommended diesels for lines with lower traffic density. But the committee also suggested an experimental installation on a suitable line based on the 50 c/s system. A private firm also asked permission to change over the London and Midland Railway's Heysham line (which was due for scrapping) from 6·6 kV 25 c/s to 6·6 kV 50 c/s. Permission was granted, and in 1952 trains equipped with rectifiers and d c traction motors ran in trial service.

The British Railways Modernisation Plan

After very careful study of the situation, the British Transport Commission in 1955 produced its plan for the modernisation and re-equipment of British Railways. This was a 15-year plan calling for a total expenditure of some £1,200 million. It sought to remedy those aspects of British Railways operation and items of standard equipment which can only be described as antique. For example, the Railways Act of 1878 made it compulsory to fit continuous brakes to passenger trains, but loose-coupled unbraked freight waggons were the general rule for freight trains in this country.

The modernisation plan called for a smaller fleet of heavier freight cars fitted with continuous brakes of the vacuum type. Track and signalling arrangements were to be improved to make high speeds possible; principal passenger stations and parcel depots were to be modernised.

Most of these changes were obviously necessary and long overdue. The controversial issues centred on changes in motive power. Would Britain follow the U S A and use diesels, or would it recommend electrification? If electrification, would it be a well-established system, or the new 50 c/s system emerging in France?

Since the electrification of a main trunk route is a long and complicated project, diesels would be used in the first place and then transferred to other lines as the electrification proceeded. The need for electrification is greatest between London, Manchester and Liverpool, and between London, Leeds and York, and a start would be made on these, in that order. Electrification would also be undertaken in dense suburban areas using multiple unit trains. London-Tilbury-Southend would be the first, followed by the Glasgow suburban system. Diesel multiple unit sets would be introduced in large numbers for branch line passenger services. This was a large, co-ordinated, expensive plan—all £1,200 million of it. But it would have cost half this amount to keep existing equipment running.

The Implementation of the British Railways Plan

After acceptance of the plan, work began on its implementation. Orders were placed with British industry and the railway workshops for the new forms of motive power; industry was to supply all the electric and diesel equipments and some of the mechanical parts, and the railway shops were to build the remainder. Diesel locomotive requirements were sub-divided into four classes, based mainly on engine h p, to suit the various freight and passenger requirements. A fifth class was subsequently added. The types were as follows:

Type 1	750 to 1 000 h p
Type 2	1 000 to 1 250 h p
Type 3	1 500 to 1 750 h p
Type 4	2 000 to 2 500 h p
Type 5	3 000 h p and over

Examples of all these types can be seen in service on British Railways today.

Typical of the Class I locomotive is the English Electric Vulcan-built locomotive of the D 8 000 series with the English Electric 1 000 h p 8-cylinder V-form turbocharged engine and electric transmission. These locomotives are intended primarily for freight and transfer work and consequently are not fitted with coach-warming boilers. The wheel arrangement is Bo-Bo and the total weight 72 tons.

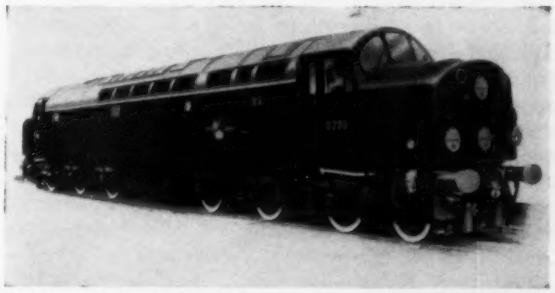


Fig 3. A Class 4 diesel-electric locomotive built by English Electric-Vulcan

An example of the Class 2 locomotive is shown in Fig 1, built by the Brush Electrical Engineering Co Ltd. It is powered by a Mirrlees 1 365 h p 12-cylinder V-form turbocharged engine and uses Brush electrical transmission. These locomotives are intended for freight and passenger work and are fitted with oil-fired coach-warming boilers. The wheel arrangement is A1A-A1A, and the total weight 96 tons.

Another Class 2 locomotive is shown on page 93. This is a 1 160 h p Bo-Bo unit, and considerable numbers of these locomotives have been built in the railway workshops. They use Sulzer engines, and all the electrical equipment is supplied by Associated Electrical Industries Ltd.

Fig 4. The Class 5 English Electric 'Deltic' locomotive, the most powerful single-unit diesel-electric locomotive in the world. The two Napier 'Deltic' diesel engines develop a total of 3 300 hp. The most significant feature of this locomotive is the very low weight-to-power ratio of 72 lb (32·7 kg) per horsepower

A Class 3 locomotive is shown in Fig. 2, built by the Birmingham Carriage & Wagon Co Ltd. It is powered by a 1 550 h p Sulzer 8-cylinder in-line turbocharged engine and Crompton Parkinson electric transmission. These locomotives are intended mainly for passenger train working and are fitted with a separate generator, driven from the main engine, for supplying power to heat the coaches electrically. The wheel arrangement is Bo-Bo and the total weight 73·5 tons.

A Class 4 locomotive is shown in Fig. 3, built by English Electric-Vulcan. It is powered by the 2 000 h p English Electric 16-cylinder V-form turbocharged engine and employs electric transmission. An oil-fired coach-warming boiler is fitted, since these locomotives are intended principally for operating passenger trains. The wheel arrangement is 1Co-Co1 and the weight is 134 tons.

In Class 5 there is, at the date of writing, only one locomotive in service—the prototype Deltic locomotive built and owned by English Electric. This locomotive is fitted with two Napier Deltic 1 650 h p triangular-form opposed-piston two-stroke engines and employs electric transmission. It can operate up to full tractive effort on one or two engines and can be used for either freight or passenger working. Most freight services can be operated on one engine. It is fitted with an oil-fired coach-warming boiler. The wheel arrangement is Co-Co and its total weight 106 tons. The Deltic locomotive is shown in Fig. 4.

Four years after the inception of the plan, the application of diesel motive power has become increasingly apparent to any traveller on British Railways.

Electrification requires rather more preparation before it can be applied. Clearances must be adequate in tunnels, under bridges, to station canopies, etc, and this involves much civil engineering work. The signalling system must suit the electrification system chosen. Interference must be avoided in telecommunication circuits and to radio and T V. The power supply system and the overhead equipment must be installed before the first train can run.

These fixed installations take considerable time to design and erect. However, much progress has been made, starting with the Manchester-Crewe, London-Tilbury-Southend, London-Chingford-Bishops Stortford and the Glasgow suburban sections.

This year, the multiple unit trains for the London-Tilbury-Southend line were put into service on the Colchester-Clacton section and are doing well; some coaches for the Glasgow suburban system have also been delivered. The first electric locomotives for the London to Manchester line are now being delivered.

In July, 1959, a white paper giving a re-appraisal of the modernisation plan was presented to Parliament. This showed that the progress made in the first four years was ahead of schedule, and that the cost of the whole scheme would be of the order of £1 500 million, mainly because of increased prices during the interval but also because of a more precise evaluation of certain parts of the plan. No basic technical changes were required, but a general acceleration of the plan and changes in the priority for electrification were suggested. Effort is now to be concentrated on accelerating the electrification of the London-Birmingham, Crewe-Liverpool, and Manchester lines for completion by 1964, and the King's Cross-York and Leeds line will be converted temporarily to diesel operation without prejudice to its eventual electrification. Excluding the Southern Region and the London Underground system, there were some 300 route-miles (482 km) of electrified track in the country in 1959. By 1963, this will have increased to close on 1 000 route-miles (1 609 km).

Modernisation must not be expected to solve all the many complex problems now facing not only British Railways but railways all the world over; but the provision of the latest forms of motive power will enable the railways to face the future with new hope and confidence in their ability to meet all demands. The British modernisation plan is a most important step forward.

This short article can only touch briefly on a few aspects of the plan, but it may encourage readers to feel that the British Transport Commission has tackled its huge task in a praiseworthy manner, and with the powerful support of British industry is effectively carrying it out. When the plan is completed, Britain should again possess a railway system second to none.

Substations for D C Traction Systems

F. G. Stevens, AMIEE*

SUBSTATIONS in d c traction systems, like those in all other systems, are the vital link between the high voltage supply and the user. In d c systems however, in addition to transforming the voltage down as in standard distribution substations, they also rectify the output to d c.

The traction substation generally performs quite a number of important functions. On the high tension side it may be used as a switching station in addition to the obvious requirements of switching in and out the rectifier equipments for supplying the track.

The transformer and rectifier equipments not only serve the purpose of supplying d c, but also of isolating the track electrically from the h v network; this is a most important point under fault conditions. The substation also acts as a low tension switching station controlling the output to the various tracks in its vicinity.

At the turn of the century the question of d c electric traction was greatly stimulated by the development of the London Underground System. At that time the mercury arc rectifier was not available although its principle had been established, and the conversion from a c to d c was therefore carried out by rotary converters. These early converters have given excellent service all over the world and some are still running to-day.

The commutation was however unsatisfactory on the 50 c/s network and therefore the h t distribution was often at a low frequency—such as 25 or 33⅓ c/s. This meant a special generating station and high tension network for the traction system, unsuitable for interconnecting with the normal supply system.

This problem was solved by the introduction more or less simultaneously of the motor converter, which was satisfactory at 50 c/s, and the mercury arc rectifier.

Because it was static and simpler to operate and install, and because of its lower maintenance, higher average efficiency and reliability, the mercury arc rectifier in one form or another has been chosen for most traction projects since 1930.

Pumpless Mercury Arc Rectifiers

In Great Britain the water-cooled steel tank rectifier with pumps and the glass bulb rectifier were both first used in the late 1920's. As early as 1927 large pumpless equipments of several thousand kW were constructed with multiple arrangements of glass bulbs, and by 1939 satisfactory pumpless steel tanks were also in use.

These two types of air-cooled pumpless rectifiers in glass or steel, which are simpler and require less attention and maintenance, easily gained favour with users and manufacturers alike. Almost all the later mercury arc rectifier development in this country has been with these equipments.

During the 1930's and again after the Second World War, large numbers of pumpless rectifier equipments have been exported from Great Britain to all over the world, and the illustrations accompanying this article show an interesting variety of destinations.

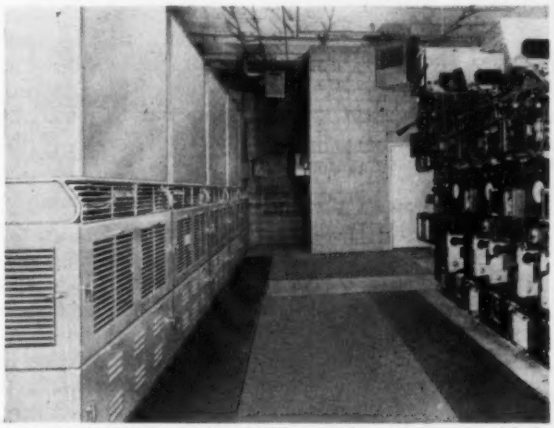
It will be seen from these illustrations that equipments for d c voltages ranging from 600 to 3 000 have been successfully exported and installed overseas. The fact that in each case a pumpless mercury arc rectifier is employed shows that this type of equipment has become accepted as the correct type of apparatus for this application.

High Speed D C Switchgear

Because the output is d c, the current relatively high, and short circuits comparatively frequent, the d c switchgear for these installations is most important.

Except in the very earliest installations, high speed single-pole circuit-breakers connected in the positive side have been used, with or without negative contactors according to the d c system used.

In the beginning, high speed circuit breakers (opening in about 0·01 seconds) were found to be a great advantage in reducing commutator wear and flashover under fault conditions. More recently they have been necessary for clearing the heavy fault currents involved as electrification systems have increased in scope. The high speed also relieves the duty on the rectifier and transformer and reduces the damage at the point of fault.



A 1 500 kW 600 V glass bulb rectifier equipment and d c switchgear in a substation supplying power to the West Side extension of the Cleveland Transit System, Ohio, U S A. All the equipment was built by the Hackbridge and Hewittic Electric Co Ltd

Broadly speaking, there are two types of high speed breaker in current use. One employs electromagnetic hold-on in which the release takes place when the flux due to the forward current overcomes the hold-on flux. The other type of high speed breaker employs mechanical hold-on in which the magnetic force of the forward current is used to upset a delicate mechanical balance.

* Manager, Rectifier Division, Hackbridge & Hewittic Electric Co Ltd

Both these types are similar in performance and are distinguished from ordinary d c breakers by the permanently energised blow-out coils with which no time is lost in building up the blow-out field in the large arc chute.

In addition to the normal h t switching equipment and the high speed d c feeder breakers, it is usual to fit a high speed reverse current breaker between the rectifier and the d c busbar. At the same time the h t circuit breaker feeding the rectifier is fitted with instantaneous trips with a high forward setting.

Thus the rectifier can be isolated very quickly in the event of a reverse direct current or exceptionally high alternating current, both of which will occur in the event of a rectifier fault.

Sometimes control grids are fitted in the rectifier which cut off the current in about one cycle in the event of a fault or a feeder short-circuit. This feature reduces the wear on the switchgear but is of course in itself an added complication.

To-day, therefore, we have an accepted arrangement of normal a c switchgear with perhaps special trips on the rectifier breakers, transformers and mercury arc rectifiers with high speed d c switchgear both between the rectifier and the d c busbars and between the busbars and the outgoing feeders, and there is no doubt that this arrangement works excellently.

Competition from other Traction Systems

In recent years this simple d c traction system has been threatened by the introduction of diesel-electric locomotives and multiple unit stock and also by industrial frequency traction systems.

There is little doubt that, for suburban traction in highly built-up areas with numerous bridges and possibly long tunnels, the advantage lies with d c traction both operationally and economically. In outlying areas where the average loading is low this system with all its operational advantages can justifiably be extended, provided the cost of the substations can be materially reduced by the special design and adaptation of the equipment for such substations.

Future Development

It is against this background that we can forecast the probable line of development for d c traction substations in rural areas. The simplest way to consider this question is to look at each item in the substation separately.

Up till now a c switchgear has always been similar in general design to that used on complete a c networks. It is however worth recording that glass bulb rectifiers, which do not depend upon the speedy opening of the a c switchgear under backfire conditions, have been successfully operated with switch fuses or fuse isolators on the transformer primary.

In at least one case this principle has been applied to a number of 1 000 kW 1 500 V rectifiers connected to a 30 kV 3-phase supply. The arrangement has worked well and could therefore be applied to any rectifier using internal fuse protection.

As regards the transformer, the significant feature in most installations is the low temperature rise of the oil in the transformer. This low rise is due entirely to the very short duration of the high current peaks, including of course short-circuits, and the fact that for most substations on the majority of systems the peak load in any case lasts for only about two hours morning and evening. The effect is even more marked in country areas where the number of trains even during the peak period is relatively small.

There does therefore appear to be scope for saving weight of both active and inactive materials in the transformer, even if it entails a slightly higher regulation. A higher regulation might in fact lead to further economies, because it would tend to spread the load between adjacent substations.

Unfortunately development along these lines tends to be hindered by the existing standard specifications, which all require that the two-hour peak must be taken after a relatively long period on full load, a condition which rarely occurs in practice.

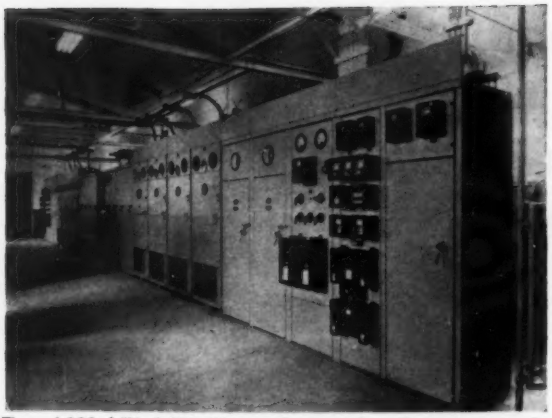
This has generally been considered to be a wise provision to meet emergency conditions in heavily loaded substations near junctions or city termini. In view of the entirely different conditions obtaining in outlying districts, it seems reasonable to have different specifications for substations in such areas so as to get the maximum economic advantage.

Two 1 500 kW 750 V pumpless steel tank equipments made by the General Electric Co Ltd of England in Rotunda substation of the Lisbon Metropolitan Underground Railway

A number of light traction substation equipments have already been constructed with smaller transformers based on the expected duration of the peak and these have been entirely successful. It is possible that in this way the main transformer equipment might be reduced in many instances to as little as half the present size without appreciable loss of safety factor under all predictable operating conditions.

A change in the design of the rectifier with economic advantages can also be made if the problem is viewed from the same angle and the rectifier banks are built to suit the special conditions of outlying substations instead of being made an all-purpose type to suit both types of substation loading.

For substations in outlying areas, rectifiers are wanted to take high peak currents following low average base



Two 4 000 kW 1 500 V pumpless steel tank equipments by Associated Electrical Industries Ltd (A E I) at Emu Plains substation on New South Wales Government Railways

loading conditions. Here the pumpless mercury arc rectifier shows to great advantage as it can be built up with standard units similar to those in the main substations, differing however in the number banked together to meet the revised loading specification. The substation buildings and the ventilation arrangements can both be considerably reduced if the plant is not required to meet the continuous loading cycle of the heavily loaded substations. Recent developments—some of them stimulated by a c traction requirements—which have reduced the size of bulb units add further to the compactness which can now be achieved for the total substation unit.

The pumpless mercury arc rectifier equipments have given, and are giving, such excellent service that users and manufacturers will for some time be averse to and apprehensive of a change. Semiconductors may however enter this field in due course by the way of these outlying substations because of their small size and wide temperature tolerance. The possibility of outdoor mounting and a simpler transformer due to the bridge connection are additional attractions.

Semiconductors have been tried with success on locomotives and multiple-unit stock, but in this case space is at a much greater premium and the load cycle more predictable. Accurate estimates of over-voltage and overcurrent conditions are essential in assessing the correct number of semiconductor cells in series and parallel.

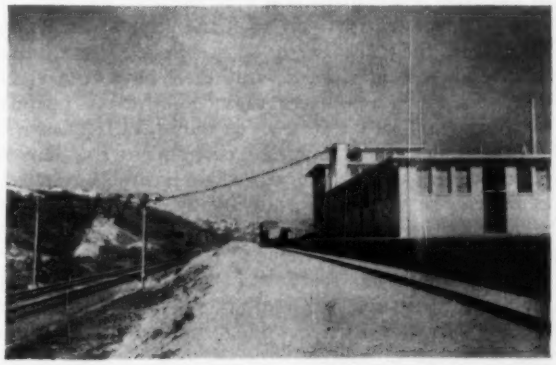
In an emergency the mercury arc rectifier can be loaded to backfire point with negligible risk of expensive or lasting damage. Means will have to be found with semiconductors for giving warning just before this point is reached, because the results of actually reaching it are likely to be much more expensive. Alternatively, it will be necessary to put so many cells in parallel that even in an emergency this point cannot be reached, but this will probably prove uneconomic.

The mercury arc rectifier is also very tolerant of over-voltage surges, so that little work has been done on reducing the over-voltages occurring in traction systems caused by switching and lightning.

For example, to prevent surge flashover some systems require clearances of the order of 4 in (10·2 cm) between the positive bar and earth. To put sufficient semiconductor cells in series to correspond with a gap of 4 in is unthinkable. Means must therefore be found of measuring and limiting these surge effects, so as to make a reasonable number of cells in series a safe proposition. Until further work has been done and experience gained it is difficult to say whether a semiconductor of equal reliability can be installed for a similar total cost.

D c switchgear may also be simplified by co-ordinated design in rural areas. For the present currents and voltages large arc chutes, installed in a dry insulated chamber, are necessary. This calls for a relatively large building and reduces the possibility of making outdoor equipment.

If, however, a higher regulation and smaller transformers can be tolerated, then the reduction in prospective fault current might well be sufficient to enable simpler and smaller switchgear to be used. Here again examples can be cited from light traction practice, of glass bulb equipments of 1 000 kW and more operating without cathode breakers and with simpler feeder breakers. This consideration applies particularly in rural areas where the impedance between adjacent substations is also high.

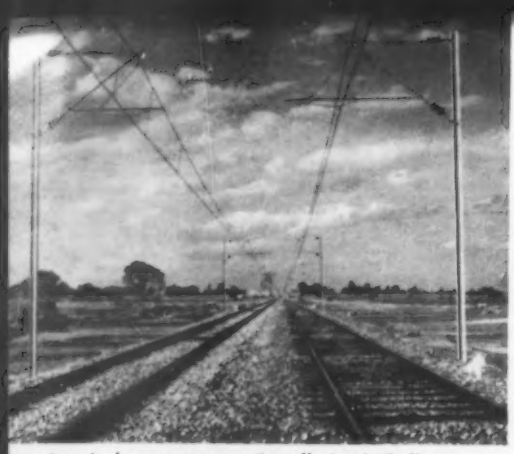


View of Tiete substation on the São Paulo–Jundiai Section of Brazilian Railways. This substation contains two 2 000 kW 3 000 V pumpless steel tank equipments supplied by the English Electric Co Ltd. Cables were supplied by British Insulated Callender's Cables Ltd

Conclusions

At junctions and in heavy traffic urban areas where a good traction voltage is essential all the time, it is likely that the present form of substation will continue. In any case, in these areas the traffic density is usually such as to justify a high investment in electrification.

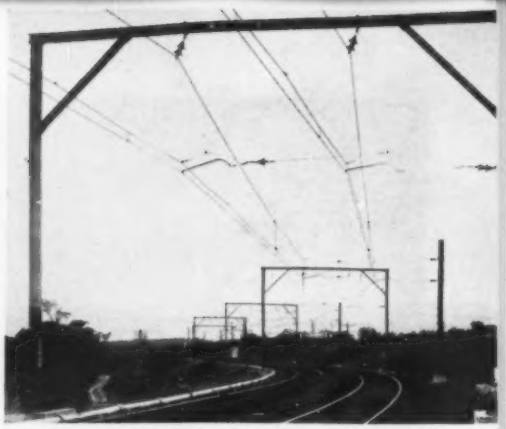
For relatively long runs in rural areas, however, a re-assessment of the requirements in the light of competing forms of traction seems to be called for. It is likely that this will lead to a more economical and more easily installed equipment. This equipment will tend by the very nature of its design to limit the duty required of both the switchgear and the rectifiers. It is in this type of substation that changes in practice may be expected in the ways that have been outlined.



A typical open route a c installation in India

Design and Installation of Overhead Equipment

D. H. Rooney, MA, AMIEE*



Two-track d c electrification in Australia

THE factors influencing the trend towards the conversion of the world's railway systems to full electric traction include the prospect of ample electric power from local sources, traffic requirements, and public insistence on clean, quiet, and speedy travel. The design, supply, and installation of the transmission equipment bringing power to the locomotive is a most important aspect of railway electrification.

System Design Considerations

In the past, electric traction systems were designed to supply direct current or low frequency alternating current to the pantograph by which the locomotive collects its power. More recently there have been great strides in the development of locomotives to operate from high-voltage a c supplies at industrial frequencies. This advance permits important economies which have a direct bearing on the choice of system. Each scheme must, of course, be considered individually in order to take account of its particular operating conditions and the nature or density of the traffic to be expected.

When comparing the cost of a d c system with a high-voltage a c scheme, a substantial overall economy favours the latter in respect of substations, feeder cables and overhead equipment. On the other hand, an a c system may involve higher costs for civil engineering and telecommunications—the latter to limit electrical interference with trackside circuits, and the former to provide adequate electrical clearances at bridges over the track and in tunnels.

Equipment Design Considerations

The system design having been decided, the copper section of the overhead conductors and the spacing of structures may be assessed. These calculations will take account of the maximum wind pressure to be expected and the range of temperatures to which the installation is likely to be exposed. Consideration must be given to the possibility of contact wire 'blow-off' in relation to the pantograph contact surface, the need for automatic tensioning of the wires, or special arrangements for high-speed running.

In such circumstances current can be collected without sparking only when the overhead equipment is designed for a flexible yet stable system. The design, manufacture and installation of fittings for integration into such a system calls for the highest standards of scientific and engineering skill. Progress in design and technique requires full co-ordination of experience in research, development, production, and installation.

Designs are then prepared for a complete range of standard equipment to include concrete foundations, supporting structures, conductor suspension and registration, overlap spans, and switching arrangements.

Modifications to standard designs, or special designs, will be required to meet the circumstances of particular locations. Such requirements will become known from the layout plans which must be prepared to show the exact position of the equipment over the tracks. Before this can be done it is usually necessary to make a full track survey, and the use of aerial photography as an aid to ground survey may be justified.

Overhead Equipment Installation

Much preparatory work has to be done before erection starts. Detailed track surveys are made to provide the required data for each support location and the final layouts are prepared for agreement with the railway officials. The design of fittings and structures and the supply of materials are closely co-ordinated with a carefully planned erection programme.

Account must be taken of proposed changes such as track alterations, station reconstruction, and modifications to signalling and telecommunications. Civil engineering work must be carried out well in advance.

Normal railway traffic must suffer as little dislocation as possible while erection work proceeds. In Britain, special mechanical plant for a number of operations has been developed which fits inside the loading gauge when not in use, and is of such shape and size that the adjacent track is not fouled while it is operating.

In countries where labour is plentiful and costs are low, a high degree of mechanisation is not economic. Mechanised foundation installation, with an auger for excavation, enables cylindrical foundations to be used which considerably reduce the quantity of concrete required. Three trains working together—the first having an auger, the second including a crane for planting masts into ground frames which hold them in position while concrete is placed from the third—make it possible to excavate, plant masts and concrete them into position alongside one mile (1·6 km) of track during a four-hour occupation. Where the ground is unsuitable or obstructions are encountered or foundations are too big for excavation by an auger, hand digging is employed.

* Director, British Insulated Callender's Construction Ltd

Where portal structures are used, one or two cranes are required to lift the bridge members.

Cranes of various lifting capacities are used for steelwork erection according to the weights of the structures to be lifted. On open route with the steel train operating between the auger and concreting trains it is possible to excavate, erect B F B masts and install foundations along one mile (1·6 km) of track in four hours.

With a c systems, on single or double track, the equipment is normally supported by single-track cantilevers. These may be erected from the trackside but for rapid installation hydraulically operated platforms of special design are used; these are also of great assistance when erecting steel-work in tunnels and under bridges.

Wiring is carried out from the flat roofs of wiring train coaches. Where it is necessary to avoid traffic interference during busy periods it is possible to carry out wiring operations at night by the aid of specially designed anti-glare floodlighting mounted on the train. A hydraulically-operated wiring jib can assist the speedy erection of conductors.

By close collaboration between the highly skilled erection teams and the railway engineers, erection programmes may be speedily carried out with the minimum of interference with the normal commercial service.

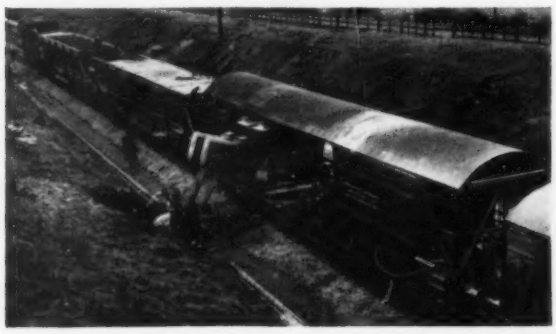
INDUSTRIAL AND POWER STATION SIDINGS

Where large quantities of heavy materials are being transported, as at power stations, at large works, in quarries, or at the pitheads of mines, electric traction provides a clean and efficient method of transport.

The coal supplies for many power stations are delivered by rail, and coal wagons have to be moved from the railway reception sidings to stock yards and wagon tipplers. In some industrial undertakings—such as steelworks—large tonnages of ore, limestone and other raw materials have to be brought in by rail and moved to storage dumps and thence to the blast furnaces or other processing plant. Generally, short hauls at slow speeds are involved but a continuous flow of material has to be maintained. For these purposes electric locomotives are pre-eminent.

Each locality presents its particular engineering and design problems; in most cases a simple form of overhead traction equipment can be provided, usually consisting of a contact wire suspended from hangers at intervals of not more than 110 feet (35 m.). Tubular steel or wood poles are the most common form of support.

Mechanised foundation installation using a special concreting train



Cantilever erection using a hydraulically-operated platform

Examples of electrified sidings include those at Kearsley Power Station in Lancashire, North Wilford Power Station in Nottingham, and at the Cleveland Steelworks in Middlesbrough of Dorman Long & Co. Ltd.

UNDERGROUND HAULAGE

Electric locomotives have been operating in mines for many years, but they have usually been of the battery-operated type or a miniature electric locomotive with a tramway type trolley collector.

The National Coal Board, however, now has two mines equipped with an electric haulage system incorporating electric locomotives with pantograph collectors and contact wires up to 0·25 sq in (161 mm^2) cross section. The wires are suspended from insulators which are attached to the roof-supporting arches, and a special feature is a device which allows for variations in span wire tension due to movements of the arches.

The locomotives operate at a d c voltage of 250 with the two rails used as the return conductor.

The systems are operating with considerable success and may well set the future pattern for the haulage of coal from the coal face to the shaft.

A former in position during concreting in a locality where labour is plentiful and costs are lower

Battery Electric Traction

A CHALLENGE FOR THE ELECTRICAL ENGINEER

P. E. McKellen, BSc, AMIEE*

Introduction

THE vast majority of existing transport and traction systems are of course powered by the internal combustion engine. Such power units use fuel which is at present freely available, are of proved reliability, and are virtually capable of running almost continually. Their main disadvantage is the high maintenance which is required. On top of all this there is the extremely heavy existing capital investment in the fuel distribution system —oil fields, tankers, refineries, and so on.

Thus the internal combustion engine is now very much the 'sitting tenant', occupying the position of the major power supplier to the transport industry. The electrical engineer who attempts to obtain with the electric motor a slice of this very rich cake has to attack this almost impregnable position held by his opposite number on the mechanical side.

The sitting tenant always has the advantage. Any new system has of course to be better than an existing one to an extent which would warrant a change-over. In the particular case of the electric motor versus the i c engine, the advantages have to be sound economic ones; such factors as silence and cleanliness do not, except in special circumstances, carry so very much weight nowadays when a change-over is being considered—although they may do so when an entirely new system is being introduced.

Thus, as far as transport is concerned, the electrical engineer really has a problem on his hands. If it were merely a question of selecting a method for a new system, electric traction would receive more attention!

Electric Traction

In many countries nowadays, and particularly in those which are more highly developed, electricity is available at a fairly cheap rate. Even in the less developed countries there is often cheap electric power—as for example from hydro-electric schemes.

Electricity can be turned into mechanical power with reasonable efficiency, very quietly and extremely cleanly. Thus the actual provision of mechanical power from electricity is relatively cheap and attractive. On the other hand the i c engine is less efficient, noisy, and emits obnoxious fumes. The provision of mechanical power from oil fuel is therefore not as attractive.

The big problem is of course the provision of the electric power at the place where it is required—that is, to the motors on the equipment when moving, and usually at a location remote from a base.

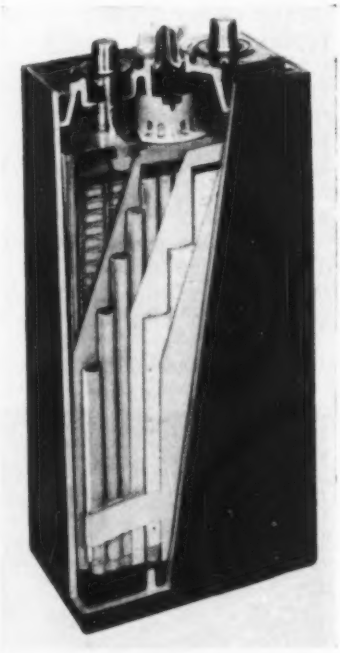
Where traffic densities are high, it is usually very economic to provide continuous feeder systems so that the electric power can be drawn off as the vehicle proceeds. This has the disadvantage that the equipments concerned must run over fixed and certainly pre-prepared routes. In cases where there is extensive development of a transport system, this is unimportant.

Obviously the most attractive way of providing electric power is to store it by some suitable method so that it can be transported with the vehicle and used where and when it is required.

All the foregoing is a summary of the fairly obvious fact that there are very distinct advantages and attractions in electric traction—particularly if using power derived from storage batteries.

Limitations of Battery Electric Traction

Although the position is now improving tremendously, there is still an amazing ignorance of the capabilities and advantages of battery electric traction. This is perhaps one of the most important limitations. Even some large potential battery operators still tend to regard such equipments as 'freaks'. The best answer to this problem is simply to persuade the 'unconverted' to talk to the 'converted'.



A cut-away section of an Exide-Ironclad battery with 'gauntlet' plate construction.

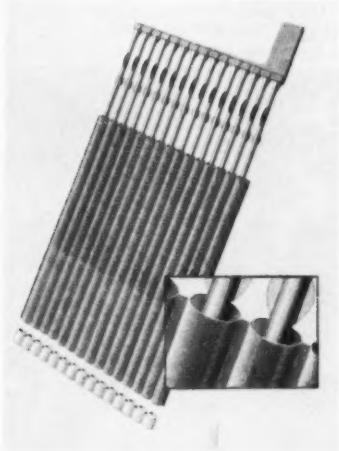
See also the illustration and constructional details on the next page.

Any device has its limitations and must be worked within them. Attempts to do otherwise can only lead to

* Engineering Manager, Chloride Batteries Ltd

dissatisfaction. The limitations of battery electric traction are essentially connected with the battery itself.

Like all storage devices, the battery has a limited capacity, the boundaries being set by space and weight considerations. The amount of power which a battery is capable of yielding over a given period does not, however, depend solely on its capacity; it depends to a great extent on the time taken to replenish the power extracted, i e the time of recharge. It is of course fairly obvious that, if a battery could be recharged in the time taken to fill a tank with petrol or oil, the i c engine would now be facing a much more serious challenge.



The new 'gauntlet' positive plate. A woven one-piece 'gauntlet' of resin-impregnated Terylene is slipped over the spines of CB 95 alloy to hold and retain the active material. It is completely resistant to sulphuric acid and oxidation, and the Terylene combines great tensile strength with remarkable elasticity

Battery engineers are continually tackling this problem of decreasing the period of recharge and quite an appreciable improvement can be obtained by using a series or system of boost charges. Such systems have however to be literally tailor-made to meet specific requirements.

In many cases the limitations at present set by the battery capacity and charging time are of little consequence. Steady but very worthwhile progress has therefore been made in battery electric traction, particularly in the last 10 years or so. As the existing boundaries formed by ignorance, battery capacity, and charging time are slowly but surely pushed back, so the applications of battery electric traction will increase.

For instance, a major step forward has been made in the last year or so by the introduction of the higher capacity batteries for traction applications. An outstanding example of this is the Exide-Ironclad 'Gauntlet' battery which provides approximately 35 per cent more storage capacity for a given weight or for a given volume than its standard predecessor of 10 years ago. The full advantages of these recent developments have not yet appeared to the user, but they do enable vehicle manufacturers to tackle new and exciting markets.

The Battery

From the early days of the electric storage battery, the lead-acid type using the lead peroxide/sulphuric acid/pure lead combination has been supreme in the traction field. This type of battery suffers slightly from its weight handicap but from all other points of view—particularly commercial—it is appreciably better than its rivals.

Some alkaline batteries (nickel-cadmium and nickel-iron) are employed for traction purposes and they generally have a longer life than lead-acid types. However, this longer life is offset by their higher initial cost.

Very interesting developments are at present taking place in the storage battery field in connection with other electro-chemical systems, particularly the silver oxide/zinc alkaline battery. This system has an extremely attractive stored capacity/weight ratio (in round figures 2 to 3 times that of the latest lead-acid batteries), but so far its cycle life is extremely limited and it is therefore scarcely considered except in special applications which have no large commercial significance. The materials employed naturally make this battery expensive, but this is offset to a certain degree by its high scrap value. If the life of a storage battery employing this system could be increased to even near that obtained at present from lead-acid batteries, then despite its higher initial cost it would have wider application.

Reverting to the lead-acid battery, it will be appreciated that the electro-chemical nature of its operation means that there is a tremendous amount of 'know-how' embodied in its manufacture. It is relatively easy to make a storage battery which is capable of storing a fair amount of electric power; it is not easy to make a battery which is capable of continually storing up and yielding its power. It is extremely difficult to make a battery which is capable of storing up and yielding its power continuously, day in and day out, for periods of up to five, six and seven years—the life expectation of a top-grade traction battery. Only a few firms in the world are capable of achieving this feat.

In view of this it is not surprising that important and progressive users of battery traction equipment employ only one or two makes of battery—those they have learned from their own experience to be thoroughly reliable and to give the life they have come to expect. The four-year life guarantee applying to the majority of traction type batteries in the British Isles really has no economic significance in these days. It was introduced in the earlier days to enable the accountants to work out firm costs and to promote the introduction of the storage battery for traction purposes. Operators who follow a policy of sticking to tried and trusted makes of batteries can now use life figures in excess of four years for accounting purposes, and to-day the four-year guarantee really serves only as a safeguard to the purchaser against unproved makes of batteries.

For the past 50 years or so the tubular type lead-acid battery has reigned supreme in this area of the traction field. Because of the nature of its construction, whereby the positive active material is contained in a porous tube surrounding a central conducting spine, it is capable of yielding deep discharges and standing up to all but continual and severe over-charges, so giving a long and reliable life. Reliability is an important feature of the well-made tubular battery. While it is, electro-chemically, extremely complicated and difficult to make, from the mechanical point of view it is relatively simple. Because of this, failure due to internal faults is rare and—more important—all the cells in the battery tend to end their life together. This is important, as the maximum use is thereby obtained from the whole battery and it is seldom

worthwhile introducing spare cells merely to get a few more months of life.

From before the first World War until recently, the Exide Ironclad tubular cell was based on this unique construction, using finely slitted ebonite tubes to contain the active material. As mentioned above, the 'Gauntlet' version of this famous cell has now appeared and employs a woven Terylene tube.

Since World War II the tremendous advantages of the tubular type of cell construction have been more generally appreciated, and in the last few years several alternative forms of tubing have appeared. The tubular cell is at present made by several companies throughout the world. The availability of a suitable tubing is, however, only about half the battle in the production of a top-grade tubular cell. The design, chemical processing and general 'know-how' are factors of overriding importance.

Battery Operating Costs

When considering the operating cost of a battery electric system, it is necessary to take into account the depreciation cost of the battery. It must be remembered that for a given amount of power extracted from the battery one has to pay for both the power itself (usually in the form of power input to the charging equipment) and for the wearing-out effect on the battery of the charge and discharge cycle.

A convenient form of assessing the wearing-out, or depreciation cost, of a battery working on a charge/discharge system is to express it in the form of 'pence per kWh'. Thus:

Battery depreciation cost is equal to:—

$$\frac{\textit{Initial Value} - \textit{Scrap Value}}{\textit{Effective capacity} \times \textit{No. of Life Cycles}}$$

where in the absence of the more practical value the effective capacity is taken as 80 per cent of the nominal.

A typical 18/20 cwt (900/1000 kg) battery-propelled milk delivery vehicle

For conventional motive power batteries, i e those having a guaranteed life of four years but with an actual life of five to six years, this figure usually works out somewhere in the region of 3d per stored kWh.

When a conventional type of rectifier charger is employed, i e one capable of carrying out a recharge in, say, between 8 to 15 hours, an overall efficiency of the order of 60 per cent may be assumed between the a c power input to the charger and the d c power output from the battery. This is essentially due to the 75 to 80 per cent watt-hour efficiency of the battery operating under such conditions and a similar efficiency of the charging equipment. Assuming an a c power cost of the order of 1d per kWh, the power cost of a kWh of d c power extracted from a battery would be of the order of 1·5d or 1·75d.

Thus it will be seen that the depreciation cost of the battery is roughly twice as much as the cost of the power used. The total power cost is therefore in the region of 4d to 5d per d c kWh used.

Where specially designed systems are used, this figure may be lowered by an appreciable amount. Boost recharging systems, for example, often have advantages of this kind, although they usually entail higher capital costs in charging equipment.

The Westinghouse automatic battery chargers in this picture are two-part equipments, with a compact remote control panel on the garage wall and the charging equipment in a separate room. The previous Westinghouse installation for this fleet of vehicles had given good service for 29 years

APPLICATIONS FOR BATTERY ELECTRIC TRACTION

Delivery Vehicles

This is, of course, an obvious and most suitable application for battery traction. A large number of delivery vehicles do a limited and regular mileage each day in a time of up to 8 or 10 hours. This leaves at least 12 hours for an overnight charge which can usually be carried out using the cheaper electricity tariff.

Where door-to-door deliveries are carried out, for instance of milk and bread, the range required of the vehicle is not great; it is limited by the physical capabilities of the driver/deliverer in visiting the customers.

For this type of work the battery delivery vehicle is easily more economic and acceptable than other forms of transport.

In 1960 there will be over 30 000 battery electric vehicles licensed in the British Isles. This compares with approximately 16 500 in 1950.

The scope of the battery electric delivery vehicle has been increased to a worthwhile extent by the advent of the previously mentioned higher capacity batteries. Additionally, more and more operators are realising the advantages of this form of transport. There is therefore a very promising future in the British Isles for these vehicles.

The potential for these vehicles is still greater outside

the British Isles. Their qualities are really only now beginning to be realised in many countries (even those with low oil costs), and their wide-scale adoption is probably only a matter of time.

Industrial Trucks

The realisation, particularly in the last decade or so, that time and money are spent and wasted in handling materials has led to a tremendous improvement in material handling techniques. In particular we have witnessed the introduction on a very wide scale of such equipments as fork-lift trucks, platform trucks and their derivatives. At the outset such equipments were produced in two versions—the i c engined and the battery electric, with the former predominating. High maintenance costs in particular, combined with the emission of obnoxious fumes in confined spaces, have however counted severely against the i c engined version and to-day the battery electrics predominate.

This is of course an extensive and growing application for battery traction and one in which the battery has more than proved itself.

The majority of equipments of this kind work one 8-hour shift only and are recharged overnight. There are many cases, however, where round-the-clock or two-shift operation is required. This is achieved by the simple method of changing batteries (usually at the same time as the driver). In cases where equipment loading is heavy, batteries may be changed more frequently than once every shift.

This system of battery changing is of course possible because the operation of the equipment is limited to an area near to the base. It demonstrates the point that, under certain circumstances, the limited capacity of a battery is no handicap.

With the majority of industrial trucks, battery changing is a simple operation which takes only two to three minutes to carry out.

Locomotive Batteries

This is a growing application for traction batteries and covers principally the narrower gauge systems used in coal mines, quarries, tunnelling operations, etc. Again, particularly in coal mines and tunnels, the absence of the obnoxious fumes of the diesel alternative combined with the relatively low maintenance of the battery vehicle are the great attractions. Almost 1 000 locomotives of this type are in use to-day in the British Isles.

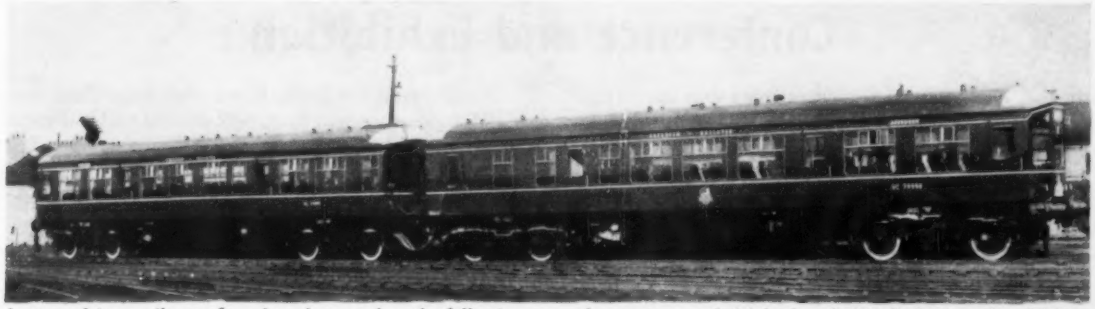
A typical example of a battery-propelled fork lift truck

Pedestrian Controlled Vehicles

There are considerable numbers of the small pedestrian-controlled electric vehicles in use. These three or four-wheeled little units are controlled by a walking driver who usually leads the vehicle. They are eminently suitable for short delivery rounds in congested areas, the range limit being set by the capabilities of the controller. Adaptations of this type of vehicle are often seen for refuse collecting in connection with road sweeping, etc. Versions are used for occasional heavy load carrying, e.g. on the platforms at railway stations, etc. It is not difficult to envisage many uses for this type of equipment.

Railcars

Mention should be made of an experiment being made with a battery-driven railcar by the Scottish Region of British Railways. This is a two-coach modified diesel unit which has been running between Aberdeen and



The battery-driven railcar referred to above and on the following page. Two electric traction motors are fitted to the bogies of the motor coach (right hand side facing) *and a driving compartment is located in both the trailer and motor coaches.* (*British Railways photo*)

Ballater, a distance of 43¼ miles (69·6 km). Boost charges are given during the day and during its daily operating period the battery yields total power equivalent to about twice its full capacity.

While a battery railcar is a novelty in this country, it must be realised that there have been very many in service for a long time on the German Railways. In that country they work alongside diesel equivalents, operating the schedules which they are capable of doing. Obviously, of course, the selection of a battery or diesel railcar depends on particular economic conditions once it has been demonstrated that the battery version is a technically acceptable proposition.

Miscellaneous Applications

As the advantages of battery electric traction become more widely realised, so do the number and variety of applications. In the last few years we have seen the introduction of the battery-operated floor scrubber and washer, the battery-operated lawn mower and a whole host of similar equipment in which, for various reasons, the limitations of the storage battery are no handicap.

Future Applications of Battery Electric Traction

There is thus still tremendous scope to increase the numbers of battery electric equipments in already accepted fields. The advent of the higher capacity battery widens each particular field as well as opening up new ones.

While the battery makers are continually attacking the problem of greater capacity for a given size and weight, it must be accepted that there is little chance of further startling increases from the lead-acid system. For these we must look to progress in other spheres: for example in the development of the silver oxide/zinc system.

The electrical engineer can however still do a lot to encourage battery electric traction. There is a need for cheaper, lighter and more efficient equipment to convert the electrical energy into mechanical power. In traction systems where power is freely available from feeder lines, the electrical engineer has not had to worry unduly about operating efficiences. Similarly, in the majority of the conventional and established applications mentioned above, operational efficiency is not very important; the equipment operates well within its capabilities. So far, therefore, the electrical engineer has not been really called on to exert his full ingenuity on the problem of producing really efficient battery traction equipment.

Fuel Cells

So much has been said recently about fuel cells that this article would not be complete without mentioning them briefly. The fuel cell is of course a name which has been given to a device which carries out a direct conversion from a fuel to d c electrical power. It is in effect an electrical generator.

By using a naturally occurring fuel, a fuel cell, and electric traction equipment, a system would exist which would replace the internal combustion engine. By generating fuel from electricity (e g hydrogen and oxygen from water) and storing it in suitable containers to be subsequently used with a fuel cell and electric traction equipment, a system would exist which would replace the storage battery electric traction system. In this application there might be advantages in the ability to re-fuel an equipment quickly by simply changing the storage cylinders rather than the equivalent storage battery.

Obviously the fuel cell would have to operate at relatively high efficiencies in order to make either of these two systems compete with conventional ones. The conversion from oil to fuel to electric power to mechanical power, via a fuel cell traction system, would have to be far more efficient than the direct conversion of oil fuel to mechanical power in an internal combustion engine. Otherwise the obviously increased capital cost of the fuel cell system would not make it worthwhile.

Similarly, for a storage system to be justified, the conversion of electrical energy into a fuel of a suitable type and in a suitable form (e g compressed hydrogen and oxygen) and its subsequent conversion back to electrical energy by the fuel cell would have to be at least as efficient as the simple storage of electrical energy in a battery.

In spite of these thoughts, however, developments taking place in fuel cells are very interesting indeed and it is possible that they will eventually be used—at least to a certain extent—in traction systems and thereby form a competitor to the conventional storage battery.

British Railways Electrification Conference and Exhibition

MORE than 200 railway engineers from five continents will be coming to this important event, which will take place in London from 3rd to 9th October, 1960.

The specialised exhibition of new electric locomotives, rolling stock and a c electrification equipment built for British Railways—the most comprehensive display of its kind yet staged in Britain—is being organised jointly by the Locomotive and Allied Manufacturers' Association of Great Britain and the British Electrical and Allied Manufacturers' Association (the B E A M A) in co-operation with the British Transport Commission.

It will coincide with the British Railways Electrification Conference, at which 41 papers dealing with the technical aspects of the 25 kV a c system of railway electrification will be presented. The opening paper will be given by Mr S B Warder, Chief Electrical Engineer, British Railways Central Staff, and during the week of the conference 10 other papers will be read by their authors. The remaining papers, which will be printed and distributed, will be discussed but not read at the conference.

The exhibition and the conference will be reviewed in the November issue of THE BEAMA JOURNAL.

THE CONFERENCE PROGRAMME: COMPLETE LIST OF PAPERS

Electrification in the Modernisation of British Railways: The choice of the 50 c/s System
S B Warder, Chief Electrical Engineer, British Railways.

The Application of the 50 c/s System as proved by System Tests
J A Broughall, British Railways and F J Lane, O B E, Consulting Engineer (Messrs Preece Cardew & Rider).

The Locomotives
E S Cox and G G Kibblewhite, British Railways.

The Multiple Unit Trains
H Willcock and C J Clemow, British Railways.

The Power Supply
W J Webb, British Railways.

The Overhead Line Equipment
E Claxton, British Railways.

The Erection of the Overhead Line Equipment
J W Grieve and A H Emerson, British Railways.

Civil Engineering Aspects
A K Terris, British Railways.

The Interference Problem
Dr H R J Klewe, British Railways.

Signalling and Telecommunications
A W Woodbridge, O B E, British Railways.

Research for A C Traction
Dr F T Barwell, British Railways.

Conclusion
R C Bond, Technical Adviser, British Transport Commission.

System Tests: Instrumentation and Measurements
W J Webb, British Railways and W Woods Hill, Microcell Ltd.

System Tests: Evaluation of Results
G H Hinds, O B E, British Transport Commission and T A Eames, British Railways.

The Consulting Engineer's Contribution to 50 c/s Electrification
E L E Wheatcroft, Consulting Engineer (Messrs Merz and McLellan).

Locomotives: Nos E 3001/23, E 3301/2
M W T Rees, Associated Electrical Industries Ltd.

Locomotives: Nos E 3024/35, E 3303/5
W G Jowett and S C Lyon, English Electric Co Ltd.

Locomotives: Nos E 3036/45
W D Morton, General Electric Co Ltd and H W Scott, North British Locomotive Co Ltd.

Locomotives: Nos E 3046/55
G R Higgs, Associated Electrical Industries Ltd.

Locomotives: Nos E 3056/95
G G Kibblewhite and F Horne, British Railways.

Pantographs for Locomotives and Multiple Unit Trains
E E Chapman, J Stone and Co (Deptford) Ltd.

Effect of Dynamic Performance of Rolling Stock on Current Collection
J L Koffman and H L Preston, British Railways.

Effect of Electric Rolling Stock on Track
J C Loach, British Railways.

Locomotives and Multiple Unit Trains under development
J A Broughall and E S Cox, British Railways.

Multiple Unit Train Equipment for Manchester-Crewe Line
M W T Rees and R Bugler, Associated Electrical Industries Ltd.

Multiple Unit Train Equipment for London-Tilbury-Southend Line
H B Calverley and E Williams, English Electric Co Ltd.

Multiple Unit Train Equipments for Liverpool Street-Enfield-Chingford-Hertford-Bishops Stortford Lines
R Ledger and J C Turrell, General Electric Co Ltd.

Multiple Unit Train Equipments for Glasgow Suburban Lines
G R Higgs and J G Sommerschield, Associated Electrica. Industries Ltd.

Power Supply: The Railway Load
W Casson, Central Electricity Generating Board and W L Kidd, South of Scotland Electricity Board.

Power Supply: Oil-insulated Switchgear
F G Rowland, Switchgear and Cowans Ltd.

Power Supply: Air-insulated Switchgear
A T Haselfoot and G T D Ingle, Fuller Electric Ltd.

Power Supply: Protection Systems
F M Pearce, Associated Electrical Industries Ltd and G T D Ingle, Fuller Electric Ltd.

Power Supply: Remote Control of Power Distribution
A H Cole, British Railways, G A Burns, A T E Co Ltd and G Gordon White, Standard Telephones and Cables Ltd.

Overhead Equipment: The Catenary System
C E Allen, British Insulated Callender's Cable Co Ltd and A Goldring, British Railways.

Overhead Equipment: Insulators
Dr C H W Clark, Steatite & Porcelain Products Ltd.

Overhead Equipment: Structures and Foundations
H H Storey, British Insulated Callender's Cables Ltd and A N Other, British Railways.

Overhead Equipment: Erection
T H Rosbotham, British Insulated Callender's Cables Ltd and I J Hall, Pirelli-General Cable Works Ltd.

Effect on Post Office Circuits
D W R Cobbe and B R Horsfield, British Post Office.

Signalling Equipment
G I Foster, Associated Electrical Industries Ltd.

Signalling Equipment
H J N Riddle, Siemens and General Electric Railway Signa Co Ltd.

Signalling Equipment
D G Shipp, Westinghouse Brake and Signal Co Ltd.

Railway Telecommunication Cables and Equipment
D R Turner, British Railways.

STANDS AT THE EXHIBITION

Stand No.	*Exhibitor*
11	H J Baldwin & Co Ltd
12	Thomas Bolton & Sons Ltd
13	The Morgan Crucible Co Ltd
14	Ferranti Ltd
15	British Insulated Callender's Cables Ltd
16	J Stone & Co (Deptford) Ltd
17	Enfield-Standard Power Cables Ltd
18	Crompton Parkinson Ltd
19	A Reyrolle & Co Ltd
20	Foster Transformers Ltd
21	Standard Telephones & Cables Ltd
22	Hackbridge & Hewittic Electric Co Ltd
23	Doulton Industrial Porcelains Ltd
24	Ottermill Switchgear Ltd
25	The Cressall Manufacturing Co Ltd
26	Microcell Ltd
27	Switchgear & Equipment Ltd
28	Associated Electrical Industries (Woolwich) Ltd
29	Nalder Brothers & Thompson Ltd
30	Fuller Electric Ltd
31	Brush Electrical Engineering Co Ltd
32	Bruce Peebles & Co Ltd
33	Switchgear & Cowans Ltd
34	The English Electric Co Ltd
35	South Wales Switchgear Ltd
36	The General Electric Co Ltd
37	Westinghouse Brake & Signal Co Ltd
38	Associated Electrical Industries Ltd
39	Communication Systems Ltd

Note. Stands 1-10 inclusive are outdoor exhibits by the British Transport Commission of locomotives, multiple unit stock and bogies.

Notes

Equipment for 380 kV System
Orders have been placed by the Central Electricity Generating Board for equipment for the first 380 kV transmission line in Britain. This is a 64 mile (103 km) line from the High Marnham power station in Nottinghamshire to the Monk Fryston substation, near Leeds in Yorkshire, and it is to be uprated from 275 kV to operate experimentally at 380 kV.

The transformers at each end of the line will be the largest ever ordered in Europe. They are auto-transformers rated at 400 MVA, 275/380 kV, 3-phase, 50 c/s and will cost about £250 000 each. They will be built by the English Electric Co Ltd and Ferranti Ltd respectively.

Switchgear has been ordered from the Switchgear Division of Associated Electrical Industries Ltd and will include 380 kV isolators and earth switches, substation connections and protective gear.

It is stated that if this development proves successful, 380 kV will be adopted as the voltage for Britain's supergrid.

Novel Use for Battery-Driven Trucks
A simple but very effective solution to the problem of delivering milk to the occupants of a new 13-storey block of flats in Sheffield, Yorkshire, has been found by using a battery-driven electric truck.

It has been designed to fit into the service lifts of the block of flats in question and to be able to turn in the corridors traversing each storey. It is powered by a 16-cell Kathanode traction battery made by the D P Battery Co Ltd of Bakewell, Derbyshire, and although only 8 feet (2·4 m) long, 4 feet (1·2 m) wide and 6 feet (1·8 m) high, it will carry 500 bottles of milk.

Using this truck means that the milkman, instead of having to carry successive loads of bottles by hand from street level to the doors of individual flats, can now drive in, ride up on the lift and propel his load along the corridors to each customer's flat.

Obviously, only a battery-driven truck could serve this purpose, since it gives rise neither to excessive noise nor objectionable fumes within the building.

Work Started on Sixth Nuclear Power Station
The C E G B recently announced its intention to award the contract for the Dungeness nuclear power station to the Nuclear Power Group—a consortium consisting of Associated Electrical Industries Ltd, the John Thompson Nuclear Energy Co Ltd and the Nuclear Power Plant Co Ltd. Site work will be started this month and the station is scheduled to come into operation in 1964.

Dungeness is designed for a net electrical output of 550 MW and will have two identical reactor units each of approximately 840 MW thermal output. Basically the design of the reactors follows that of earlier stations, but incorporating the latest developments in reactor and heat transfer technology. They will be of the gas-cooled graphite-moderated type using natural uranium in magnox cans.

Five nuclear stations are now under construction in Great Britain—four in England and Wales for the C E G B, and one in Scotland for the South of Scotland Electricity Board, with outputs ranging from 275 to 500 MW. Consent has also been given for a seventh station at Sizewell, which will have an output of 650 MW.

New Light Fitting Helps Overhead Electrification
A good deal of the installation work on British Railways electrification schemes has to be done at night, and illumination has been supplied by portable flood-lights or by low-wattage fixed tungsten bulkhead lights. In practice these produced an inadequate and uneven distribution of light.

Working in close co-operation with B I C C and the Chief Mechanical and Electrical Engineer of British Railways Eastern Region, Falk Stadelmann & Co Ltd have now developed a completely new fitting designed to comply with the rolling stock gauge regulations and strongly constructed to match the severity of the operating conditions. It consists of a single fluorescent lamp in a galvanised heavy duty mounting and a special aluminium reflector to give maximum illumination at working level.

The new fittings have been installed on the construction trains used by B I C C for the electrification of the Eastern Region of British Railways. By fitting four of these units to each carriage, an illumination of about 5 lumens per square foot (929 cm^2) is obtained at contact wire level. Power is supplied, via roof mounted waterproof sockets, by a 250 V 50 c/s generator fitted inside one of the vehicles in the wiring train.

Further Orders for Diesel-Electric Locomotive Equipments
Crompton Parkinson Ltd now have on order 98 sets of 1 550 h p Type 3 diesel-electric locomotive equipment for the Birmingham Railway Carriage and Wagon Co Ltd, the locomotives being for use on British Railways Southern Region.

The design of the Type 3 equipment includes provision for electric train-heating, applied to diesel locomotives for the first time in this country. Compared with Type 2, a larger and more powerful Sulzer diesel engine is fitted in the space saved by the elimination of the steam boiler and water tanks and this drives a Crompton Parkinson generator set which provides current for traction and for heating and auxiliaries.

The main generator is rated at 1 012 kW at 750 rev/min. The main, train-heating and auxiliary armatures are mounted on a common steel rotor, with the train-heating generator at the engine end of the main frame. A train heating voltage of approximately 800 V is maintained at all speeds from 550 to 750 rev/min. The auxiliary generator has a continuous rating of 57 kV at 110 V throughout the engine speed range.

The four series-wound traction motors are operated in parallel across the main generator. They have a continuous rating of 305 h p 440 A 580 V, and drive the axles through resilient gears.

The total of Crompton Parkinson equipments for British Railways, either supplied or in manufacture, now amounts to 292.

A delegation from the British welding industry recently visited the U S S R at the invitation of the State Scientific and Technical Committee of the U S S R Council of Ministers. This will be followed in September by a reciprocal visit to Britain by a party of Russian technical experts. The exchange of visits was arranged by the B E A M A.

The British delegation was led by Mr D J W Boag, Managing Director of Rockweld Ltd. Other members of the delegation, seen here on their return to London Airport, included (left to right): *Messrs R H Boughton (English Electric Co Ltd); W S Simmie (Pressed Steel Co Ltd); G H Moule (A E I (Manchester) Ltd); T F Tribe (British Federal Welder & Machine Co Ltd); G M Harvey (British Oxygen Gases Ltd)*

The World Power Conference

MADRID SECTIONAL MEETING

S. Z. de Ferranti *

Editor's Note. *The first World Power Conference was held in London in* 1924. *During these* 36 *years of its active and fruitful existence it has gained world-wide authority and support in the pursuit of its primary objective: the development and the peaceful uses of energy resources to the greatest benefit of all, both nationally and internationally. There are now* 59 *member-countries represented on the International Executive Council.*

Plenary meetings take place every six years, and the Sixth World Power Conference will be held in Melbourne, Australia, in October, 1962. *Sectional meetings are held usually every two or three years, and the Madrid meeting was the sixth sectional meeting of the post-war series.*

Of the 167 *papers presented,* 17 *were by authors from Great Britain, and their important contributions to the proceedings are summarised in the following article.*

Of the many vivid impressions left by the Sectional Meeting of the World Power Conference held in Madrid from 5th to 9th June, two were outstanding. First, the attendance was a record for a Sectional Meeting and reflected the level of interest engendered by the Conference theme of 'Methods for Solving Power Shortage Problems'. Second, the papers and the discussions which they aroused served to emphasise the leading part which the U K is playing in technical development and achievement through the efforts of its engineers in the electricity supply, research, manufacuturing and consulting fields.

Developments in Genererating Units

A major contribution in the field of conventional electric power generation was the paper by Booth and Dore of the Central Electricity Generating Board: 'The Development of Large Electricity Generating Units', in which the authors traced the stages of development, especially in the post-war period. While stressing the early recognition of economic gains based on increase of unit size, (gains thought to be 20 per cent in cost per kW for 100 per cent increase of unit rating), they gave due credit to manufacturers for having made, through the combination of technological advances and improvements in manufacturing efficiency, gains in real costs of manufacture averaging $2\frac{1}{2}$ per cent per annum exponentially.

The pattern of the advantage taken of 'size effect' after 1954, at which time 30 MW and 60 MW units were the rule in plant commissioning programmes, was traced up to the point at which 350 MW single-line turbo-generator units were adopted. In the light of such limiting factors as conditions of transport for large units in the U K, this was a tremendous gain, and an important contributory factor was of course the technical advance achieved by machine manufacturers in rotor and stator cooling techniques.

The interim development of the 550 MW two-line unit was touched on, and the authors stressed its importance in terms of evolution from the 275 MW single-line unit from which it largely stemmed.

* Managing Director, Ferranti Ltd

Clear economic advantages had been established, so that it was in the main line of technical advance and in no way a freak.

The attractions of 'size effect' had not resulted in any lack of attention to the less spectacular gains to be made by advances in steam conditions. In a contribution to the discussion, Mr E B Johnson (C E G B) announced that, after full comparison of the 350 MW subcritical arrangement with a supercritical design for 375 MW, an order for two of the latter units had been placed by the C E G B despite a slight adverse economic balance. Adverse balances of this kind, (as also mentioned by Sir Christopher Hinton in a nuclear context) are often worth incurring in the initial application of a new development. The present case is believed to mark an important step forward in the development of generating practice. As a corollary, it was mentioned that the C E G B had also issued formal enquiries for a 500 MW unit incorporating a single line turbo-generator.

The Pattern of Nuclear Power Progress

In the field of nuclear power, particular interest attached to the introductory lecture given by Sir Christopher Hinton. Emphasising the progress made since 1953, when nuclear power plans were first announced in the U K, he pointed to the steady economic gains that had been made and indicated the technical objectives of the next decade.

Sir Christopher stressed that no apology need be made for mistakes since the nuclear plan was started, or for changes of plan that have taken place, as these were the unavoidable price of progress. For example, he doubted whether the present form of graphite moderator had a long enough service life for reactors of the future, and he thought that replaceable graphite might have to be employed for the conditions envisaged. This development is expected to flow from a joint U S A/U K project which has been launched.

The earlier optimism regarding the cost of nuclear power had been tempered by events in both the nuclear and conventional power fields. Capital cost per kW of available power, however, continued to be the dominant

factor. A further fall in this cost depended on developments in terms of unit size, an aspect which is currently receiving the particular attention of research and development teams.

Sir Christopher's remarks paved the way for extensive discussions, which served to emphasise the large scale response which has been given to the favourable U K conditions for development and experiments in the nuclear field. These developments are being closely watched by the many countries which are unwilling or unable to incur parallel costs but are keen to have firm bases on which their own nuclear power plans can be built up.

Mr R D Vaughan (The Nuclear Power Plant Co Ltd) developed the case for expectation of continued improvements in nuclear plant efficiency, cost per kW and cost per kWh on the basis of the trends in these and other relevant factors since the inception of nuclear power plans in the U K. After making allowance for cost reductions achieved in later stations due to redesign of various plant items and improvements in techniques leading to simpler and cheaper layout, Mr Vaughan was firmly of the opinion that the major economic gains of the gas-cooled reactor have been due to the increases in gas pressure and output progressively achieved in manufacturers' designs.

These two factors were cited as the basis for expectations that the Dungeness and Sizewell power stations will have a specific plant cost about 30 per cent lower than that of Bradwell or Berkeley and that the net station efficiency will be several points higher. The trend of generation cost per kWh from 1961 to 1966 in respect of gas-cooled reactors was fairly steeply downward, but these reactors had yet to come into service, and after 1966 much seemed to depend on the advanced gas-cooled reactor, an experimental version of which was in course of construction at Windscale.

Nuclear Power Economics

The paper by Hinton, Brown and Rotherham (C E G B): 'The Economics of Nuclear Power in Great Britain', developed this theme of costs in greater detail. The demands for increasing thermal efficiency and lower capital costs were linked with higher temperature conditions, and it was stated that the Windscale advanced gas-cooled reactor is an attempt to make a very significant step forward in outlet gas temperatures. This has led to the use of a modest degree of fuel enrichment, a feature which more than one speaker in the discussion deprecated as inherently uneconomical in the U K. The authors claimed however that the extra cost was fully offset by the reduction in the number of fuel elements used.

Higher temperatures were not an end in themselves, it was emphasised, as optimum design calls for interrelation of cycle efficiency and reactor heat output—both of which are temperature dependent—with circulator power requirements. Nevertheless, as in conventional plant, more advanced temperatures may offer means of obtaining economic advantages.

Progress in design was perhaps most sharply demonstrated in terms of the heat rating of fuel. For the original Windscale plant this was less than 1 MW per ton, and for Calder Hall 1·4. The rating was between 2 and 3 MW per ton for Berkeley, Bradwell and Hinkley Point, while for the projected plant at Sizewell, the figure expected is nearly 4. A major step forward to 8 MW per ton is expected for commercial plants, based on the advanced gas cooled reactor at Windscale, which could be available by 1970.

Forecasting Energy Requirements

Discussions on methods of investigating energy requirements revealed a widespread interest in this subject and a leading part was taken by U K members, in particular those representing the electricity supply industry and consulting engineers. A review by Messrs Beard and Pedder (of the firm of Merz & McLellan) of available methods of forecasting electrical requirements served to demonstrate how the fundamentals of the techniques and their implications for supply undertakings, particularly in overseas markets, have been the subject of study. Apart from countries such as those of the Eastern European bloc, where the development and demand for electricity is governed by a 'plan' rather than by economic, climatic and other factors, forecasts of load development are a major criterion governing capital availability. Mr Geoffrey Kennedy (of the firm of Kennedy & Donkin) stressed the interest in this subject which has been generated by the concern of the World Bank to ensure the proper allocation of capital for power projects, and he emphasised the need for proper study of all the factors involved rather than reliance on a single mathematical model.

The rule-of-thumb basis of load doubling every few years or so, which had served highly developed countries in the past, is being overshadowed in many cases by 'regressive' or tapering-off rates of growth.

Among the many factors calling for study were kWh per capita; growth in number of consumers; growth by consumer groups; daily and weekly load curves; special factors such as lack of generating or distributive capacity; the existence of special tariff rates, and hire purchase facilities.

The fundamental difference of approach to developed and under-developed countries was highlighted by the contributions of Mr Hunter (Sir Alexander Gibb & Partners) and Mr Cash (C E G B). Whereas Mr Hunter stressed that the major problem lay with under-developed countries, where the doubling of demand every few years was a completely unacceptable basis for forward projections, Mr Cash was able to demonstrate that, for the post-war period at least, the growth of demand for electricity in the U K had been at a substantially steady percentage rate annually.

These were among the high spots of a discussion from which it emerged that forecasting, to a large extent, continued to depend on judgement based on intimate knowledge of the governing factors in any energy field, coupled with a wealth of experience in that field. The leading part which was being played by U K electrical engineers, both on the consulting and operating sides, was a measure of their awareness of the vital role which forecasting had to fill in the planning of new projects, both in the U K and overseas.

were acknowledged by Mr King, and he agreed that means of generation not subject to similar limitations

Mr Nelson agreed that the generation and distribution of electricity lent itself particularly well to the use of

of the Convention. The Rt Hon Viscount Chandos, DSO, MC, is delivering his Presidential Address

Electrical Horizons at the BEPC

THIS year's British Electrical Power Convention,* held during the first week in June at Bournemouth, looked ahead: to the new horizon for electricity. Four papers covered respectively the future of electricity supply, electrical exports, electrical manufacture, and electricity in the home, and each was followed by a lively and informative discussion. On the last day of the Convention, a selection of questions sent in by delegates were answered by members of the Electrical Forum.

Looking back on the whole convention, it is possible to see the various areas of agreement and controversy on future electrical developments. Broad developmental changes such as the continuing rise of power consumption with the standard of living, or the future importance of stations burning nuclear fuels, generally were agreed. More controversial were the detailed aspects of generation and transmission, and of the manner in which electricity would be used by industry and by the housewife.

Future Generation

In Britain, as in many other countries, there has been a steady growth in electrical demand at a rate of some 7 per cent per annum cumulative over the last thirty years. Commenting on this fact in his paper on 'The New Horizon—Electricity Supply', Mr C R King, Chairman of the Electricity Council, pointed out that there were no indications of any slackening in this rate of growth. As a result, forward planning in Britain has led to the movement from a two-fuel to a three-fuel economy. By 1964/5 coal consumption by power stations is expected to increase by eight million tons to a total of 50 million tons, while oil consumption is expected to increase by the equivalent of one million tons of coal. In the same year, the third fuel—fissile uranium—is expected to provide the energy equivalent of about five million tons of coal. Five nuclear stations will be in commission by then.

The cost of nuclear generation was discussed several times during the convention. In his Presidential Address, Viscount Chandos put forward the view that the newest nuclear stations, after allowing for the amortisation of capital, would produce energy at equal cost to a conventional station if the latter had to buy coal at as much as £4 per ton. As pit-head stations now buy coal at £3 5s 0d per ton, the economic gap between the most favourable conventional stations and nuclear stations amounts to 15s per ton of coal at the pit-head. The Hon H G Nelson, Managing Director of the English Electric Co Ltd, emphasised in his paper 'The New Horizon—Electrical Manufacture' the complications of comparing the economics of coal and nuclear power stations. But he considered it reasonable to expect that by the end of this decade electricity for base load operation would be produced more cheaply from nuclear stations than from coal stations.

Mr King suggested that an advanced gas cooled reactor might well be installed in the electricity supply system by the end of the 1960's. This type should show appreciable economies in both capital and running costs and might be competitive with conventional stations at lower load factors. Looking further ahead, he thought that by the early 1970's a commercial fast breeder reactor might be in commission, with even lower capital and running costs than the A G R. Such a reactor would make use of the plutonium by-products of earlier reactors. Mr N Elliott, of the South-Eastern Electricity Board, agreed with Mr King that the fast breeder reactors were promising sources of power, but suggested that thermonuclear fusion would be even better. There were grounds for confidence that by 1970 there would be devices for producing it that might break even economically.

Mr King took a less optimistic view of the rate at which thermonuclear energy would become incorporated in the power network, but thought it would be a practical proposition within the lifetime of the next generation.

Towards Higher Efficiency

In his paper, Mr King stated that the average thermal efficiency of conventional plant during 1964/5 is expected to reach about 29·6 per cent, as compared with 26·10 per cent in 1959. As far as future individual efficiences are concerned, the 550 MW units at Thorpe Marsh Station are expected to attain figures of about 36·5 per cent. This point was remarked on by Mr Elliott during the discussion. While agreeing that the increase in efficiency was commendable, he suggested that no industry that threw away about two-thirds of its raw material could be proud of itself. Something fundamental had to be done; diminishing returns were being obtained by the production of larger and larger sets. There had to be a breakthrough into something new.

The thermodynamic limitations of the steam station

*THE BEAMA JOURNAL, 67, No 2, p 74

Mr R J Lane, of Preece, Cardew & Rider (Consulting Engineers) drew attention to the problem of the space that was likely to be taken up by very large high-voltage

requires great pressure. This can only be achieved by powerful electric motors specially designed for operation in an explosive atmosphere

were acknowledged by Mr King, and he agreed that means of generation not subject to similar limitations should be sought. Basic studies and experiments are proceeding on the generation of electricity direct from hot furnace gases by taking advantage of their ability to conduct electricity. The magnetohydrodynamic method, as it is called, could render conventional boiler plant and turbo-alternators unnecessary. The capital costs of generators of several hundred MW capacity should be comparable with that of conventional plant. For relatively small-capacity installations, thermoelectric and thermionic generators were already showing promise; so also were fuel cells, which in the long term might provide a means of energy storage for load-factor correction. Mr Nelson, however, doubted whether any of these sources of power would be competitive within the next 20 years, but he suggested that it was possible for steam turbines to be obsolescent by the end of the century.

The manner in which turbo-alternator sets would develop in size was a matter for controversy at the Convention. Mr Nelson pointed out that if the post-war trend were to continue we should have 1 000 MW single-shaft sets in operation by 1970. However, at present he considered it did not seem possible to design a generator larger than 550-600 MW, owing to the 200-ton restriction on loads carried by road, and the strength required by the end bells of the machine. Assuming advances in technology but no revolutionary discoveries, he envisaged that cross-compound double-shaft sets of 2 000 MW might come into operation during the 1970's.

Economics of Generator Size

In the discussion which followed, Mr F H S Brown, of the Central Electricity Generating Board, said he thought it more probable that there would be single-shaft machines of about 800 MW in the 1970's. With units of this size the capacity of the links in the grid system might become more important than the capacity of the system as a whole. If the size of a single unit exceeded the capacity of a single transmission line, it would need more than one line to cover the outage of such a unit, so that if the economic return from the larger units was small their installation might not be attractive.

Whatever the future trend in generator size may be, the past growth has paid off remarkably well in its reduction of capital cost. As Viscount Chandos pointed out, 12 years ago the cost per unit of power installed was about £65; now it is down to about £39.

An aspect of development raised by both Mr King and Mr Nelson, and provoking little controversy in discussion, was the manner in which automatic techniques were entering power generation to an increasing extent. Mr King stated that on average, the manpower engaged in operating the Board's steam power stations to-day works out approximately at 1·5 employees per thousand kilowatts of sent-out capacity. This compares with a figure of 2.8 recorded 12 years ago. Stations planned for commission during the next two or three years will have figures as low as 0·3 to 0·4. Automisation of generation plant is in fact now almost a theoretical possibility, and a considerable amount of work is being done to make it practicable. The Generating Board's approach is first to achieve fully remote control at West Thurrock Station and then to employ a computer to control the operation.

Mr Nelson agreed that the generation and distribution of electricity lent itself particularly well to the use of electronic data processing and automatic control. Within a few years, he suggested, the automatically controlled station could become a reality. The next stage would be to control a group of such stations to secure the most efficient distribution of load between them. It may well be, he concluded, that it is along these lines that the most significant economies are to be found.

Transmission Lines

In Britain we have the world's largest interconnected grid system operating at 132 kV, and within the last few years sections of the 275 kV supergrid have been brought into operation. Mr Nelson drew attention to the fact that the development of the bulk transmission of power in this way was a pressing problem in many parts of the world, particularly where there are vast resources of water power remote from electrical demand. In the U K he foresaw that higher voltages would be desirable, particularly to make use of existing wayleaves. 500 kV seemed to him a logical next step in the U K; and overseas, 750 kV or more might be necessary.

During discussion on this topic, Dr D S McIlhagger, of Queens University, Belfast, recalled that with the development of better insulation the towers for the 275 kV system could be used for 380 kV. At present there had not been sufficient development to make this possible and the only way to increase the voltage of transmission lines was to increase the length of insulator strings. He urged that research should be directed in a massive way to discovering how breakdown across insulator surfaces could be prevented—or else research should be concentrated on the manufacture of underground cables.

D C transmission was commented on by Mr Nelson, who explained that the relative economics of d c and a c transmission were being actively considered, but that the difficulties of switching d c tended to confine its use to long distance point-to-point transmission rather than in networks. Mr King pointed out that the only section of the Generation Board's system yet planned to operate on d c is the cross-Channel cable link with Electricité de France, due to go into commission next year.* He considered, however, that within the next decade or two it could well be that a case for d c transmission would be established by the possibility of large scale exports of hydro-electric power from North Scotland to England.

Dr McIlhagger suggested that there would be serious difficulties with insulators in a d c transmission system. There would be problems of electrolysis which would lead to destruction of metalwork, erosion of insulator surfaces, and early breakdown under poor atmospheric conditions. With a c transmission the forces of capacitance helped to produce uniform distribution over the insulator surface, but these forces were lacking in d c transmission, in which voltage distribution could be controlled only with conductance. He urged that attention should be devoted to producing a semiconducting insulator, or an insulator with a satisfactory semiconductor glaze, which would not erode away near a corona discharge.

*THE BEAMA JOURNAL, **63**, No 4, p 156; **64**, No 4, p 175, **65**, No 4, p 164

Mr R J Lane, of Preece, Cardew & Rider (Consulting Engineers) drew attention to the problem of the space that was likely to be taken up by very large high-voltage substations. High voltages of up to 500 kV would have to be led into the heart of urban areas and large spaces would not be available. High-voltage substations would have to be much more compact.

Mr Elliott questioned whether the increased transmission capacity was really necessary. The estimated transfer of energy from the Birmingham area to Thames South and Northern areas in 1964/5 was equivalent to the transport of 7½ million tons of coal a year. He questioned whether lines should be erected for this purpose instead of transporting the coal.

Mr King suggested that in order to meet the demand for more compact substations with lower levels of noise and lower dissipation losses, we might have to turn to the electronic field, where a start has been made on the production of miniature transformers and circuit breakers using semiconductor techniques. Mr Nelson agreed that vacuum switching and semiconductor devices might provide scope for further developments in the next ten years, but suggested that at present there were severe capacity limitations to such devices, and some major breakthrough would be required before they could be applied to very high ratings.

During the Electrical Forum, Mr Elliott took up this point again and expressed the hope that semiconductors would replace switchgear for low and medium voltage, and in the long run for high voltages also. Mr S F Steward, Director of the B E A M A, emphasised that semiconductors were bound to re-establish the use of direct current and d c techniques in transmission, and would have an effect on switchgear and perhaps rotating machines.

Industrial Expansion

Mr King suggested that industry, in addition to increasing motive power per worker, would use more devices for control purposes and would continue to use electricity for heat processes on an ever wider scale. An electric steel-making plant is scheduled for operation in Sheffield in 1963 and will have a capacity of well over one million ingot tons, consuming some 750 million kWh per year. It is likely to be the forerunner of other installations of a similar size.

Mr Nelson also recognised a growing use of electricity as a processing element, giving as examples the progress of the aluminium industry and that of uranium enrichment plant. In many industries, electric power has made available a speed, accuracy, and concentration of power without which the products could not be made. A striking example is polyethylene, production of which requires great pressure. This can only be achieved by powerful electric motors specially designed for operation in an explosive atmosphere.

Mr Nelson considered that the greatest innovation now unfolding in industry was the linking of electronic data processing to control. So far the two have been mostly limited to continuous processes, but the extension of such techniques to other forms of manufacturing has already begun and should make significant progress in the next few years. Already programmes can be prepared so that, by feeding the parameters of a transformer specification to a computer, it will issue paper work in the form of stores requisitions, work cards, etc. It is but a step to issue the instructions in the form of punched cards to machines that will operate machine tools. Computers will also replace guesswork in a wide area of business problems by up-to-date factual knowledge, as a basis for rational thinking.

The Electric Home

In his paper 'The New Horizon—Electricity in the Home', Mr T E Daniel, Chairman of the British Electrical Development Association and Chairman of the North Western Electricity Board, pointed out that it was not a question of what was technically possible but more one of exploring what form the pattern of living was likely to assume. More compact refrigerators were likely as a result of the development of semiconductor devices capable of replacing the conventional cooling unit. Electric cookers, however, had shown such a remarkable change in the last two or three years that it was not easy to forecast what further developments there would be in the next ten. Separation of the oven from the hob seemed a desirable step, and possibly twin ovens would be fairly extensively produced, at least one being fitted with a rotary spit. The electronic oven might have made sufficient strides for it to be used for the very rapid heating of prepared meals stored in the refrigerator. And the use of a thermostatic probe to control roasting temperatures was likely.

Summing up, it can be said that the electrical horizons envisaged at the Convention were wide and inspiring. This is not surprising, as one of the most characteristic features of the electrical manufacturing industry in Britain is its high spending on research and development. Whereas British industry in general spends 2·6 per cent of its turnover on research and development, the electrical industry spends 9·8 per cent. The great advances foreseen at the Convention depend on this massive technical effort.

Editor's Note. *Mr C R King, C B E, (as he was at the time of the Convention) is now Sir Robertson King, K B E.* *(see page 84)*

The Electrical Forum at the Convention.

The members of the panel are (left to right), *Mr N Elliott, Chairman, South Eastern Electricity Board; Mr S F Steward, Director of the B E A M A, who is speaking into the microphone; Miss Mary George, Director of the Electrical Association for Women; and Mr A R Cooper, Member for Operations including Nuclear and Personnel, C E G B*

The 1960 CIGRE Conference

T. M. H. Stubbs, A C G I, A M I Mech E, A M I E E

THE 18th bi-annual convention of the International Conference on Large Electric Systems—CIGRE—was held in Paris in June last. More than 1 800 delegates from 44 countries were present and during 17 sessions of discussion, against a background of 150 papers and reports, practice and developments in the many specialised aspects of high voltage power generation, transmission and control were under consideration.

To avoid the necessity for many simultaneous discussions, several subjects are discussed at alternate Conferences. Direct current transmission is one of these subjects, and was last discussed in 1956. This session attracted a large number of delegates.

Direct Current Power Transmission

Two d c transmission schemes have now been in commercial operation for several years—the Sweden-Gotland cable link, and the Kashira-Moscow overhead line connection. Under construction are the cross-Channel d c link (160 MW at $\pm$ 100 kV) between the British and French a c 50 c/s systems, and the Stalingrad-Donbas transmission (750 MW at $\pm$ 400 kV). As was known, a d c connection between the North and South Islands of New Zealand has been the subject of study. Projects are also under consideration in Canada and Italy, and in Venezuela there is the interesting possibility of a long d c power transmission to interconnect two a c systems having different frequencies. A further indication came from U S A, where a major project for full scale experimental work primarily to solve problems of transmission at 460 and 650 kV a c has provision for experimental work on a line operating at 2 $\times$ 600 kV d c.

Discussion opened with reports from Mr Von Geiger (Sweden) and Mr Kostenko (U S S R) on operational experience with the Gotland and Kashira-Moscow links respectively, from which it was clear that no major difficulties have arisen. Indeed, as Mr Von Geiger pointed out, the Gotland scheme has been in operation for more than five years and, excluding the first 12 months, the system had given 92 per cent availability, while during the present year only one interruption from a fault on the d c side has so far occurred. From Mr Kostenko's account of the 112 km Kashira-Moscow link, the principal difficulty had arisen from the non-ignition of valves and location of the particular valve at fault. Much work had had to be done to reduce the original very high level of radio interference and damping circuits had been introduced to eliminate surge voltages.

D C Transmission at 800 kV

A detailed report from Russia on the design of the new Stalingrad-Donbas transmission stated that the capital cost between a 500 kV a c system and a $\pm$ 400 kV d c system had been found about equal, but the d c scheme had been adopted because this line will eventually be used as part of a much larger transmission scheme.

The Cross-Channel Link

On the other project under construction, a most interesting and valuable paper came from Messrs Cherry and Paines (Central Electricity Generating Board) and MM Sallard and Tellier (Electricité de France) on the problems arising from the design and construction of the d c link by submarine cable between the French and British a c systems. It appeared that the present limit for single core cables from an insulation point of view is around 300 kV, taking into consideration the severe mechanical stresses inherent in submarine work.

The cross-Channel link was originally investigated on the basis of 132 kV 3-phase a c and subsequently the decision was made to use d c. M Laurent, commenting on the French point of view, summed it up by saying that investigations had shown that a link between the French and British systems would be an economic proposition with a c but would be still more economic with d c. There were, he said, indications now that the cost of the d c conversion equipment would be higher than originally estimated but would be outweighed by the exceptional opportunity to gain experience with a 160 MW d c link in operation between two large a c networks.

Mr Stalewski (C E G B) gave details of a new experimental station which will be located at the old Acton Lane generating station in London. Using British equipment, it will be used for studies of problems on high voltage transmission. The experimental transmission system will have a rating of 63 MW at 70 kV, 900 A, with single anode valves having a mean current rating of 300 A. The immediate objectives are to gain operational experience with back-to-back working and as an asynchronous system link.

On radio interference, a special study has been made of the expected signal-to-noise ratio at the English terminal of the Channel link at Lydd, and this was the subject of a paper from Messrs Martin and Prewett (C E G B) which gave details of test measurements made in Sweden at the Gotland terminal and a detailed study of the conditions and suppression measures necessary at Lydd. It appears that, at sites such as Lydd where broadcast and television signal strengths are low, adequate suppression of interference can be achieved provided that the screening and filtering are catered for at the planning stage. Even so, the cost will be considerable and may add up to 50 per cent to the cost of a conventional building. For the converter plant station at Lydd a building of 378 000 cubic feet (10 700 m^3) is expected to cost £90 000—some 40 per cent more than that of a conventional unscreened building.

Another aspect of interference arising from d c

operation was referred to by Dr Rusck (Sweden), who described investigations into the effect on ships' compasses of d c cable currents, the conclusions from which were that the course corrections required are very small in comparison with those a navigator needed to make for winds and tides.

A C High Voltage Transmission

The first point for discussion was that of the choice and standardisation of voltage levels above 400 kV.

The situation, as outlined by the special reporter M Francis Cohen (France), was that so far two voltage steps above the 200-230 kV nominal (245 kV max) in general use had been recognised by the International Electrotechnical Commission: namely, the 275-287 kV nominal (300 kV max) and the 380-400 kV nominal (420 kV max). The first of these originated in California and had since been adopted by Great Britain, Japan and other countries; the second was mainly in Continental Europe—in Sweden, Germany and France; was temporarily in the U S S R and will be used in Finland and Switzerland.

Different voltage levels have however appeared. In Russia the existing 220 kV systems are to be uprated to 330 kV. The 400 kV lines in Russia would be progressively increased to 500 kV-525 kV because of the large amounts of power to be transmitted over long distances and because the margins that existed in the insulation of the first 400 kV lines allowed of such increase. New main transmission systems in Russia would be designed for the 500 kV-525 kV level. In the U S A a level of 345-362 kV is in use and, as the I E C level of 380-400 kV is considered too close, the trend there is to consider 460 kV as best suited to present needs and a level of 576-604 kV is being investigated for the future.

New E H V Voltage Levels

The Study Committee had in mind the desirability of avoiding unnecessary multiplication of new e h v levels, but it was evident that opinions were not unanimous on any proposal. Proposals from two different approaches were included in the report. The first, from Messrs Sporn and St Clair (U S A), suggested the nominal voltages of 345 kV, 500 kV and 690 or 750 kV—the European 400 kV to be regarded as a variant of the 345 kV level. The second proposal by M Ailleret (France) was that the present I E C levels of 220-230 kV (nominal) and 380-400 kV (nominal) be accepted and a new standard level of 660-690 kV (nominal) 735 kV (max) be introduced.

In discussion Dr Roser (Germany) gave reasons why his country had decided to continue with 380-400 kV for at least the next few years. A small step to a higher level would be uneconomic, and it would be impracticable to introduce such a step in Germany unless the 380-400 kV level, on which there was already substantial development, were abandoned. Mr Lalander (Sweden) said that a voltage higher than 380 kV could have been chosen for the main Swedish transmission system, but for the foreseeable future Sweden had decided to continue with 380 kV, installing series capacitors, where necessary, for stability. Studies had shown that whereas a 40 per cent investment saving could be made by an increase from 225 to 380 kV, a further increase to 500 or 600 kV gained only a few per cent.

An American view came from Mr Wagner, who thought the I E C value of 380-400 kV not sufficiently high for long distance transmission nor for backing up an existing network. The only way to avoid the appearance of numerous voltage levels was to have an adequate standard range.

Mr Casson (C E G B) thought it must be appreciated that when supply engineers concluded from operational experience and appreciation of design margins that the uprating of an existing transmission system was the most economical solution to a problem, it would be done. Thus new voltage levels could arise, but common sense would prevail and recommended voltages would be adopted if not too restrictive. It would, he thought, be necessary to establish five new voltage levels.

Long Distance Power Transmission Problems

Stability, auto-reclosure, corona losses and radio interference were the subjects of a number of papers.

From Sweden came a detailed report on the 400 kV transmission where the long distances make stability an important factor when planning extensions. All known means of raising stability limits have been compared and the series capacitor is widely used because of its convenience, flexibility and economy. Studies have shown that by their use, compensation up to 40 per cent on a 400 kV line with twin conductors can increase the capacity of the line from some 400 MW to 600 MW, and with triple conductors from 450 MW to 700 MW.

Mr Abetti (U S A) gave details of the results of extensive computer studies to determine optimum values for the number of conductors and their cross-sections and of series capacitors over distances up to 500 miles (805 km). The results were in general similar to those obtained in Sweden.

A report from Russia dealt with problems on several transmission systems. The 400 kV Kuibishev-Moscow transmission has two single lines 780 and 860 km (485 and 534 miles) in length where compensation is obtained by the use of a single series capacitor battery placed at the midpoint between the two busbars of a cross-connecting substation. It was stated that this installation increased the capacity of the system by 350 MW.

Single- or Three-pole Reclosing

Single-pole and three-pole automatic reclosing both found advocates. M Dretsch (France) and M Renchon (Belgium) spoke of the comparatively low cost of single-pole reclosing and of its reliability. Mr Norlin (Sweden) thought that it was impracticable on lines longer than 150 miles (241 km) because the residual arc would not be extinguished. On the other hand, its advantages were pronounced where a system has many radial feeders. Three-phase reclosing was referred to by Mr Sporn and Mr St Clair (U S A) who spoke of the very satisfactory operational experience on systems in the U S A and said that the cost of conversion to single-pole reclosing could not be justified.

In a discussion on switching and transformer substation design in relation to protective measures, Mr Casson (C E G B) said that for large stations in Great

Britain the use of a double busbar arrangement with section switches and busbar protection was favoured. He mentioned recent experiences with 275 kV coastal switching stations where, as a result of storms, salt spray on insulators had resulted in eighteen busbar faults in three days. Washing of the insulators by water spray had given no lasting remedy and at such exposed positions 275 kV substations would be of indoor construction.

Earth Wires

Opinions were expressed on the need for earth wires in overhead line construction where auto-reclosure is applied. Mr Jancke (Sweden) said that earth wires had been dispensed with on the 230 kV lines of the Swedish system but had been retained on the 380 kV lines as having a useful mechanical function as part of the tower structure.

M Cabanes (France) thought that earth wires were a source of trouble in themselves, being vulnerable to icing and corrosion; they were superfluous with modern protection equipment and had already been removed to some extent in France.

The last subject considered in this session—corona and radio interference—indicated that radio interference is regarded as of greater importance than corona loss, and one speaker advocated the establishment of a standard to set an acceptable level.

Two interesting reports dealt with experimental lines under construction in U S A and Canada. The American line known as 'Project E H V' is 4·3 miles (7 km) long, its route having elevations from 950 to 1 080 feet (290 to 330 m) above sea level in Western Massachusetts where it will be subject to widely varying weather conditions. It will be operated at 460 kV and 650-750 kV, and several stations will be elaborately equipped to record and assess experimental information on corona, radio interference and mechanical behaviour of the line.

The Canadian experimental line, the 'Coldwater Project', comprises two 3-phase bundled-conductor test lines operating at 600 kV. Here again the object is to determine radio interference and corona loss characteristics of particular bundled-conductor arrangements.

Insulators

The problem of pollution—both industrial and salt—has been greatly increased with the higher transmission voltages now in use, but development has been inhibited because no proved laboratory tests have been available to assist designers. A significant step forward appears to have been made by an international committee of experts under the chairmanship of Dr Forrest (C E G B Research Laboratories).

Introducing the report, Dr Forrest thought it could be said that reliable artificial tests on the performance of insulators were now available which will give a realistic appreciation of the service performance of insulators. A number of different types of insulators had been tested at different laboratories in various parts of the world by five methods and good correlation had been obtained with four of them.

The discussion on pollution problems showed that experiences in many countries raised many common problems. There was wide agreement that greasing of insulators improved their performance under polluted conditions but some differences appeared as to whether petroleum jelly or silicone grease was to be preferred, and on the method of application. Mr Connon (C E G B) referred to the heavily polluted atmosphere in the north-west of Great Britain where, especially during fog conditions, many faults occurred. Greasing of insulators was considered impracticable and he described a system for routine washing of insulators now in use on live 275 kV gear at Carrington.

Salt Pollution Problems

Difficulties arising from salt pollution were referred to by delegates from widely separated countries. An interesting point was made by Mr Tinney (Eire) in referring to a gale in 1959 when 17 flashovers in 24 hours due to salt-laden air caused severe damage to substation equipment. The transformer bushings, of the same insulation level as the other equipment, did not flash over, and as they were heavily loaded at the time it was assumed that hot air rising around the bushings had prevented deposits of salt.

Tests of the resistance of large porcelain insulators to sudden temperatures changes—thermal shock tests—were discussed on the basis of a report from the study committee. Non-destructive testing by ultrasonics has also been under consideration although no conclusions have yet been reached.

A new design of insulator having helecoidal sheds was the subject of a paper by MM Gion and Meier (France). This design has reduced the overall length for a given voltage and the helicoidal sheds enable the turns to be placed close to one another to obtain adequate leakage path with shallow sheds.

In discussion M Gion claimed that test results confirmed that the insulators suffered little damage under power arcs. Such insulators are in service in France and units are to be tested in Great Britain and Switzerland.

Circuit Breakers

This year two papers of general interest were concerned with new developments in circuit-breaking media. The first, from Messrs Browne and Leeds (U S A) on the use of sulphur hexafluoride (SF_6)—a dense gas five times the density of air, originally applied in 1953 to a load-break switch for currents up to 600 A and now applied to circuit-breakers having breaking capacities of 10 000 MVA at 138 kV and 15 000 MVA at 230 kV. Gas is stored at 14·5 atm absolute and blasted through arcs at three pairs of contacts in series per pole, exhausting into main tanks held at 3 atm pressure.

The second paper came from France and dealt with the use of high-pressure compressed air, of the order of 10 to 20 times the pressures now used, in the development of circuit-breakers having increased breaking capacities at the high voltages.

Post-arc current problems were the subject of three papers and evoked discussion on theoretical and experimental data on their form and amplitude but, as some speakers said, it was to be regretted that the results of measurements available were on prototypes and not on designs in production. The main point that emerged and is still not answered is whether post-arc conductivity itself adversely affects the behaviour of a circuit-breaker.

Turning to the testing of circuit-breakers, an interesting paper came from Mr Roxburgh (A E I (Rugby) Ltd) on the development testing of a circuit-breaker for a 330 kV system during which a single-phase 380/132 kV auto-transformer was available, and comparative tests of magnetising current interruption with that and the transformers in the test station were made and compared.

Discussion centred mainly however on several papers dealing with indirect test methods, particularly synthetic tests, but again doubt was raised as to the validity of such tests which, it was held, should be corroborated by direct tests made on a network if they were to be of value as development tests.

Turbogenerators used as Synchronous Condensers

The use of turbogenerators as synchronous condensers was one of the subjects discussed, and a paper by four C E G B engineers reviewed the reactive power requirements of the British transmission system and tests made on a 25 MW and on a 30 MW steam turbine generator operating as a synchronous condenser. It was shown that the use of turbogenerators to provide reactive power is both technically and economically sound in stations which are normally manned and where steam is available for running the sets without affecting the normal routine. Provided a full vacuum at 28·2 in (716 mm) Hg was maintained, the turbine could be motored without overheating with the stop valve shut.

Mr Horsley (C. A. Parsons & Co Ltd) said that interest in the use of turbogenerators as synchronous condensers appeared to be increasing in various parts of the world. While the simplest drive was by its associated turbine, there were advantages to be gained by uncoupling the turbine and starting the generator through spare busbars or by means of a special motor-generator set. He described such a large unit now being developed for Canada and in which the control will be fully automatic.

Transformers

In the transformer section, the first of three preferential subjects was large auto-transformers, the use of which has been increasing for the interconnection of new extra-high voltage transmission lines with existing h v networks. In addition to eight papers from as many countries, problems peculiar to this type of transformer were reviewed by Mr Rippon (C. A. Parsons & Co Ltd) on behalf of the international study committee.

Discussion showed that practice and opinion on the need for and the rating of delta-connected tertiary windings, voltage regulation, and impulse protection differ widely. Examples were quoted of large 3-phase units in service without tertiary windings. All 132/275 kV auto-transformers on the British grid have delta-connected tertiaries which can be opened. Similarly, opinion differed on the type of impulse protection necessary for the h v and m v terminals. What became clear is that a surprising rate of development in size and rating of large autotransformers is continuing, and before the next C I G R E Conference ratings of more than 300 MVA at 400 kV may be in service.

On dielectric tests the consensus of opinion was that an additional switching surge test is unnecessary, the present test practice producing transformers having an interent surge strength appropriate to the voltage rating.

Artificial Cooling of Cables

Of the several subjects discussed in the cable session, that concerned with the artificial cooling of cables as a means of increasing load capacity was the most topical. Messrs Ralston and West (Canada) presented an interesting account of projects in which cooling pipes were incorporated in several buried cable installations. Their conclusion was that load capability can be increased by 50 per cent—a conclusion with which, in general, a mathematical analysis by Mr Giaro (Italy) of forced air circulation in a cable shaft was much in line. From Messrs Sutton and Morgan (Enfield Cables Ltd) came the possibilities of uprating 200-300 kV cables by the application of forced cooling for which, it was held, oil-filled cables with oil circulating in a central duct appeared to be best for circuits of a length less than 1 km. Above 1 km a water-cooled pipe type cable was more suitable.

A report from Messrs Hawley, Hewitt and Hacke (Associated Electrical Industries Ltd) referred to the original development of a water-cooled cable for field coils for the synchrotron at Glasgow University based on which a three-core 20 kV cable has been designed for generator connections, each conductor having its own central duct. Using moderate water pressures over lengths of several hundred metres, it is suggested that current carrying capacity can be increased by a factor of two or three.

A paper from M Ondin (France) reported on two years' operation of a 500 kV 1 400 MVA cable with forced-oil cooling and an account of a similar cable for 380 kV.

Mr Ashford (Pirelli-General Ltd) described a water-cooled cable having 24 segmental-shaped cooling channels, 240 yards (219·5 m) in length, installed at Uskmouth.

In discussion many test and practical experiences with forced cooling of cables by oil, gas or water were given. There was general agreement that economics are very important, particularly as the length of the connection increases. Capitalised losses could be very high and each case must be studied. But forced cooling for short lengths is practical.

The organisation of the 1960 sessions maintained the high standard of previous conferences. Delegates had the opportunity of making one of three technical visits: to the Montereau thermal power station and 380 kV substation, the Champagne-sur-Seine works of Le Matériel Electrique S A, or the research and testing centre of Electricité de France.

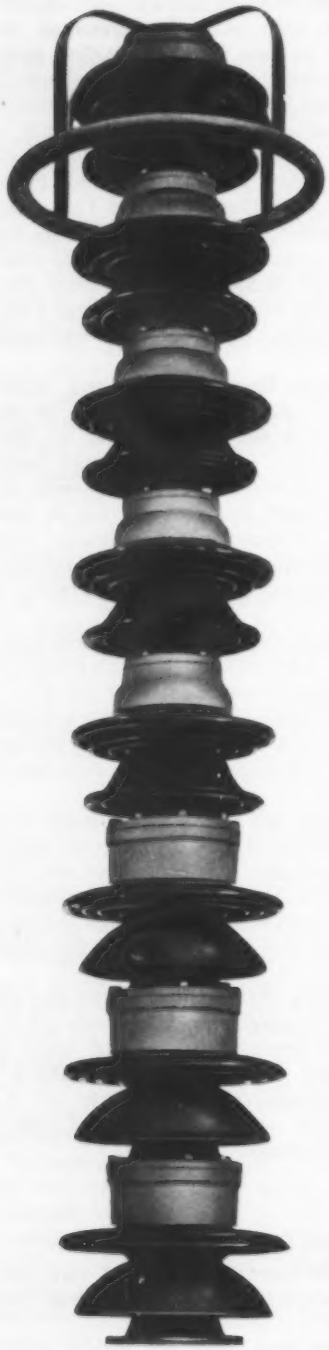
* * *

THE 1962 CONFERENCE

The dates for the 19th meeting of C I G R E have now been announced. The Conference will take place from 16th to 26th May, 1962.

It will be noted that these dates are slightly earlier than those which have been chosen in the last few years, and this has been done in order to avoid both Ascension Day and Whitsuntide.

New equipment and processes



A Doulton 275kV 8-unit post fitted with grading ring for use as busbar supports for CEGB substations

Heavy Duty Insulators for Extra High Voltages

The range of heavy duty post insulators made by *Doulton Industrial Porcelains Ltd* has recently been extended to include designs for a working voltage of 275 kV, and these have now received full approval by the Central Electricity Generating Board after extensive proving tests. The new units enable the manufacturers to quote for requirements for working voltages up to 330 kV, and publications giving full details will shortly be available.

Chief electrical characteristics include: minimum flashover with corona ring—dry 580 kV, wet 580 kV; minimum flashover without corona ring—dry 830 kV, wet 680 kV; 50 per cent impulse flashover positive—1 400 kV with corona ring, 1 550 kV without corona ring.

Fault Detector for H V Power Lines

An electronic fault detector has been developed by *Ferranti Limited* of Edinburgh in co-operation with the North of Scotland Hydro-Electric Board to facilitate rapid location of faults on 132 kV grid lines.

Development of the detector was initiated by the Board, whose interest in electronic methods of fault detection arises from the fact that many of its 132 kV lines lie across mountainous country, which is extremely difficult to traverse, especially in winter.

The types of fault that can be expected fall into three broad categories: latent, sustained and transient. An example of a latent fault is an impaired ground clearance of a conductor, which will not cause flashover at normal voltages. A sustained fault can be produced by a broken conductor or a badly damaged insulator string. A transient type of fault occurs when lines clash during a high wind or when lightning strikes the line. The North of Scotland Hydro-Electric Board has one type of fault which commonly occurs during the winter: ice accretion on the lines. This begins as a latent fault, since the conductors merely sag. It develops eventually into a sustained fault when the conductors sag sufficiently to touch the ground or each other.

The type of fault locator developed by Ferranti is the so-called radar type locator. This works on the radar principle of pulse reflection, the reflection in this instance being caused by any local variation in line characteristic impedance. The distance to the fault can be found by measuring the time interval between the sending of the pulse and the reception of its reflection.

The d c locator developed by Ferranti is stated to have performed very well under test conditions with the North of Scotland Hydro-Electric Board. It has successfully located staged faults under varying conditions and it is hoped that it will be able to detect the onset of icing conditions before the lines sag sufficiently to touch the ground.

This type of locator is however only regarded as a preliminary step since it is restricted in the type of fault that it can detect and any live line fault of a transient nature is beyond its scope. In view of this, further development is proceeding on an a c type of locator, with a view to covering fault conditions on both 132 kV and 275 kV lines.

Standard Hydro-electric Units

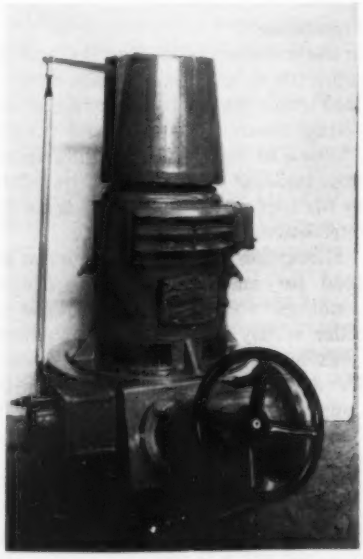
A range of small standard hydroelectric units has been developed by *Gilbert Gilkes & Gordon Ltd*, of Kendal, Westmorland.

Designed to provide a simple and reliable source of a c power in remote and isolated areas, these units cover a power range from 5 to 25 kW and are suitable for heads of water between 90 and 300 feet (26·5 and 91·5 m).

The compact arrangement of the equipment consists of a Gilkes Turgo Impulse Wheel overhung on the lower shaft extension of a vertical shaft alternator. Water is supplied to the turbine through a spear regulator of normal design which obviates the need for an inlet valve if the pipeline is short. Speed control is by means of a jet deflector operated by a shaft governor of new design mounted on the alternator.

It should be noted that this is a governed unit producing alternating current at standard voltage and frequency, and it can be used to operate normal domestic, agricultural and small industrial equipment. The alternator is of the well-known Stamford design and has a simple static excitation and regulation system housed in the control panel. Voltage regulation is very close at all lagging power factors, and 50 or 60 c/s alternators can be supplied for any voltage up to 550 V, single or three phase. The units are designed for tropical conditions and altitudes up to 10 000 feet (3 050 m).

Further designs are being developed for outdoor installations, for direct mechanical drives to small mills or other machinery, and for asynchronous units to operate in parallel with existing power systems.



A prototype unit of the range of small hydro-electric generators produced by Gilbert Gilkes & Gordon Ltd

'Waste' Worth £70m a Year

A E A'S INDUSTRIAL ISOTOPE RESEARCH PROGRAMME

J. Stubbs Walker

RADIOACTIVE isotopes, many of them the waste products of atomic reactors, will eventually save British industry something in the neighbourhood of £70 million a year. Their use in such things as process control, precise and continuous measurement, the sterilisation of foods and medicines, on-the-spot radiography and the mutation of plants to produce hardier and more fruitful crops has already become a practical proposition. After a regrettably slow start, there are now signs that industry is beginning to appreciate the width of the isotope's field of useful activity.

This considerable potential importance of the industrial use of isotopes is the main purpose of the £800,000 isotope research station at Wantage, in Berkshire, set up by the United Kingdom Atomic Energy Authority and officially opened—some months after it had been in operation—by the Minister of Science, Lord Hailsham. It is the reason why the A E A has recently opened a comprehensive Isotope Information Bureau, aimed principally at knowledge-seeking industrialists, at the London headquarters at 11 Charles II Street, S W 1.

The need for these two complementary services arises from the unmistakable fact that British industry generally has been reluctant to make anything like the fullest use of isotopes. Already, according to Dr J L Putnam, head of the Wantage Isotope Research Division, these radioactive particles are responsible for a direct saving of £3½ million a year in British industry. But that figure, he says, could be £16 million if full use were made of the facilities offered by radioactive waste. In twenty year's time (again, Dr Putnam's estimate) the use of radioactive isotopes could mean an annual saving to industry of at least £70 million.

Package Irradiation Plant

The laboratories at Wantage do everything possible to put the isotope on a purely engineering footing. Throughout, the accent is on the practical use of the radioactive tool and the outstanding example is an irradiation processing plant occupying an area of some 10 000 square feet (929 m²). This is capable of sterilising some three tons of packaged products by irradiation from an isotope source—medical supplies, animal fibres or, when further experimental work has been done, food intended for human consumption.

It is the first plant of its kind in the world. It has a 120 000 curie source of cobalt-60 and the goods to be sterilised are automatically fed on to a conveyor belt system which carries them through the irradiation cell, contained in a thick concrete blockhouse. This, with its massive shielding walls, occupies an area of 1 000 square feet (92·9 m²) and contains the radioactive source in the form of a cobalt 'bomb'. There are two conveyor systems through the cell, and the speed at which they travel can be varied over wide limits so that the degree of radiation can be changed.

The basic idea is that packages to be sterilised are of one cubic foot (0·028 m³) each and the reason for the two conveyor systems is to make use of all the radiation emitted. One system passes close to the source, the other travels on an outer track. This method enables radiation that passes the inner line of goods to reach the outer line. Naturally, there is a difference in the amount of radiation received by the inner and the outer circuits, but as the systems are operated independently, the inner line can pass through the cell much faster than the outer so that the amount of radiation can be balanced.

Each package passes the source ten times, five with one side exposed and a further five with the opposite side facing the source, so ensuring that the contents are evenly irradiated. When the system is not operating, the cobalt-60 is lowered into a water pool beneath the irradiation cell, thus giving further shielding.

Eighty per cent of the capacity of the plant is reserved for the sterilisation of medical equipment, for clinical trials and for packaging and storage tests before the pilot plant is put into full-scale production. The remainder of the capacity is taken up in the research and development programme of the Technological Irradiation Group at Wantage.

Britain exports radioisotopes to 58 countries all over the world. This photograph shows a consignment being loaded into a special wing-tip container at London Airport

Another of the Wantage activities is in the use of gamma ray sterilisation of disposable plastic hypodermic syringes and other medical equipment. It has already been proved that these cheap instruments, made of thermoplastics, can be thrown away after one use without putting up the costs at a hospital, for they are as cheap to replace as the conventional instrument would be to clean and sterilise.

Sterilisation with gamma rays has another value: the process produces almost no temperature change in the object being treated, so that rubber and thermoplastics can be handled without danger of damage. Though this is not an example of the work at Wantage, it shows the wide use that the medical profession is making of radioactivity: for several months, 10 000 catheters a week have been sterilised in an installation at Harwell, using spent elements from research reactors as the radiation source. It is significant that hospitals using the irradiated catheters have reported a considerable drop in the number of infections.

New and Cheaper Radioactive Material

At present, cobalt-60 is the most commonly used of the heavy radiation sources, but work is going on to produce a much cheaper material, caesium-137, a waste product of reactors. It is a complicated substance to separate, and canning the caesium presents technical difficulties. Windscale, however, is already operating a small-scale separation plant which will eventually produce about 1 500 000 curies of Cs-137 a year and this may be followed by further plant with more than ten times the capacity. Once the problems of handling caesium have been overcome, it will almost certainly be the cheapest of all high radiation sources.

The use of radiation for the preservation of food is a study of considerable importance at Wantage. So far, it is by no means a perfected process because the degree of radiation required, the sometimes quite noticeable change in flavour of the substance and occasional discolouration, are problems still not completely understood. One thing, though, has already been proved, and that is that potatoes or onions that have been given a comparatively small dose of radiation can be stored for many months without sprouting. Wheat and corn can be irradiated to kill bacteria, but the commercial aspect of this kind of treatment still requires a good deal of work on it before it can be considered economic.

Liquid Flow and Leakage Measurements

Thickness gauges and instruments for measuring the contents of tanks by means of isotopes are already fairly widely used industrially, but there are several original methods which have been or are being developed at Wantage. For instance, there is a system of using radioactive tracers to measure and examine the flow of liquid in a closed channel. Measurements of this kind, which are important in commissioning hydroelectric generators, can be made with an error of less than one part in two hundred. Another method of remarkable accuracy is to measure the leakage in small hermetically sealed parts, such as the casing of a transistor. The casing is placed under pressure in a radioactive gas, krypton-85. Using a sensitive detection device, leakages into the container of the order of one ten-thousandth of a cubic centimetre *a year* can be recorded. This is done by measuring from *outside* the container the amount of radioactivity that has seeped in.

The measurement of very thin surface coatings employs a fluorescence spectroscopy technique using radioactive sources. This is already employed industrially to measure coatings one ten-thousandth of a centimetre thick, even to measure the thickness of ink on paper. In the electroplating industry, it has been possible to study for the first time the action of some of the additives commonly used to brighten and level the plated deposit by mixing with them radioactive tracers. The tracers were detected by 'micro-autoradiography' in which the active material takes a photograph of itself, its intrinsic radiation being captured by a photographic plate.

An obvious method of saving money in industry is to use a radioisotope instead of an X-ray generator. In the examination of steel castings, for instance, a 250 kV machine, required for steel up to an inch or so (2·54 cm) thick, would cost from £3 000 to £5 000; to produce a radiograph of a large casting, four to six inches (10 to 15 cm) thick, would call for a 1 500 kV machine, the cost of which puts it out of reach of a small foundry. Yet a small piece of cobalt-60, costing less than £50, would do the same job as a 2 MV X-ray machine. Because of its small size—little more than 1 in (2·54 cm) long and a 0·25 in (6·35 mm) in diameter—it can be placed in positions quite inaccessible to an X-ray machine.

Plant Mutations

On a slightly more esoteric plane, there are possibilities of using nuclear radiations for producing dramatic changes in crops. This is really a method of speeding up the ordinary activities of nature by producing mutations. In nature, a mutation appears and survives only if it represents a suitable change. To 'prove itself' might take generations. By speeding up the changes, the plant breeder can select the successful mutations and dispose of those that are of no value, without waiting for the long-drawn-out process of survival of the fittest.

This is still a field of uncertainty and experiment, but, says Dr D Roy Davies, one of the Wantage experts, useful variations have been induced in many species of crop plants.

In Sweden barley, wheat, oat, pea, soya bean, flax and mustard mutants have been produced which vary in yield, straw strength and other characteristics. New varieties have resulted in some instances. These include a higher yielding white mustard, oil-rape and pea and a stiffer-strawed barley. One report from Sweden quoted by Mr Davies claims a barley mutant which flowers earlier and can thus be grown in more northerly latitudes. German reports quote cereal variants having higher grain yield, up to eight days earlier flowering, stronger straw, higher protein content and improved disease resistance.

In Britain, a self-fertile form of cherry has been produced from the normally self-sterile type. This should be less dependent on insects for pollination and therefore should give a better yield in colder regions or during unfavourable seasons.

Dr Davies sums up the mutation position: 'In Britain there is in general very little enthusiasm for the technique, and in America the mood of tremendous optimism of a few years ago has changed to one of extreme caution. In Sweden and Germany, where during the last twenty or thirty years so much has been done to exploit the technique, there is much optimism that it can make a significant contribution to plant breeding.'

Cargo Transporters in the 'Canberra'

LOADING AND UNLOADING THROUGH SHIP'S SIDE

ELECTRIC traction finds application in large liners, an interesting example being provided by the machinery for loading cargo on and off the ss *Canberra.** Instead of having cranes loading freight through deck hatches, the two after holds are served by transporters that operate through doors in the side of the ship. From the central cargo trunk amidships, a horizontal boom can be extended over the quay on either side of the vessel; along the boom runs a carriage with electrically driven hoist and traverse mechanisms, able to pick up cargo straight from the quay. The operation is controlled from a cab mounted on the carriage.

The transporter, made by Carron Company, will handle various items, including passengers' baggage and motor cars. It ingeniously avoids the break-up of the deck line and the loss of passenger accommodation that is usually involved when cranes serving deck hatches are used. In addition, loading and unloading is simplified and speeded up, as the cargo does not have to be hoisted clear of the top deck. Only one operator—in the cab, with the cargo in view at all times—is required; and the overall weight of the equipment is less than that of the conventional crane arrangement.

There are two identical transporters on the ship. Each consists of a structural steel boom carried on rollers within the ship. Housing the boom within the ship in this way protects the whole mechanism from the action of salt spray and weather. The boom can extend 30 ft (9·15 m) outside the ship and its movement into position and the opening of the side doors for it are controlled from a push-button panel. An electric motor winches the boom into its extended position, electrical interlocks preventing this occurring if the doors should fail to open. Extension of the boom takes less than 1½ minutes. Once the boom is out, the hoist and traverse mechanisms of the carriage can be connected to the main electrical supply.

Power is taken to the carriage by way of B I C C fully guarded overhead conductors carried on the underside of the boom. Mounted on the carriage is an electric motor driving through gear boxes on to four barrels that hoist the four wire ropes attached to the cargo platform. Different platforms are used for lifting cars and luggage. When the car platform is in use, the hoist ropes are arranged in a double-purchase tackle and a lifting capacity of three tons (3 050 kg) is achieved. For handling luggage a single-purchase tackle is used, doubling the lifting speed but reducing the capacity to 1½ tons (1 525 kg). Changeover from one platform to the other can be made in a few minutes, using quick-action shackles and pins fitted with safety locks.

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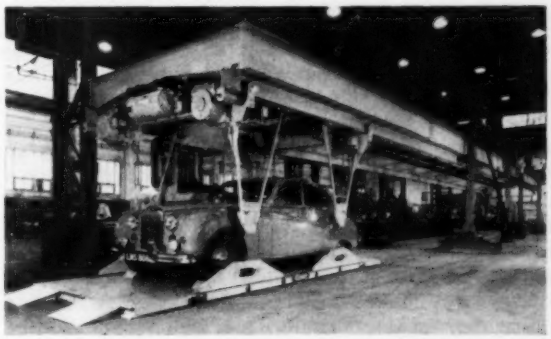
From the quay, a car is driven on to the car platform of the transporter under its own power. The operator then hoists the platform at about 60 ft/min (18·3 m/min) until it is just under the carriage; it is locked in this position to supports on the carriage. Moving at 125 ft/min (38 m/min), the carriage traverses along the boom into the ship, by means of a winch driven by an electric motor, and comes to rest over the hatch trunking leading to the lower decks. Limit switches control the approach to this position. Lowering of the car to the deck where it will be stowed follows, limit switches again being used to indicate when the required deck level is being reached. The platform has a total possible vertical travel of 45 ft (13·7 m) inside the ship and is guided by four T-section guides fixed to the side of the trunk.

Passengers' luggage can also be handled by two smaller transporters of 10 cwt (507 kg) capacity. These are also made by the Carron Company and are of somewhat simpler design than the larger transporters. They will be controlled by push button from inside the ship, and boom and carriage will travel simultaneously.



The transporter in the erecting shops before installation in the Canberra. *It is shown with the boom extended, the platform lowered, and the car ready to drive off. The first temporary support on the right of the transporter is in the approximate position of the ship's side*

Carron Company were responsible for the design and construction of the cargo transporter; Allen West & Co Ltd supplied the control gear; Dewhurst and Partner Ltd the brakes; and Sir William Arrol & Co Ltd built the boom. Electric motors were supplied by Bruce, Peebles & Co Ltd and by Associated Electrical Industries Ltd, Rugby.

Carron Company are also supplying the major part of the galley and pantry equipment for the *Canberra*, comprising electrically heated island ranges, steam-jacketed boiling pans and similar items.

The Third I E A Exhibition

THE fast-growing range of equipment available for developing automatic systems was on display at Olympia, London, last May at the Instruments, Electronics and Automation Exhibition. This was the third of this series of biennial exhibitions which started in 1956, and it showed that there is no lack of firms anxious to put industry on the road to automation. Twice the size of its 1958 predecessor, the exhibition housed nearly 500 exhibitors from 15 countries.

Accounts of actual experiences in the use of electronic equipment were given in a three-day conference, 'User Experience of Electronics', held at Olympia during the exhibition. Speakers from the petroleum, glass, tyre, aircraft, steel, and motor industries gave details of how they had taken advantage of new electronic techniques, and offered a glimpse of the depth of penetration into industry that the many thousands of exhibits in the adjoining halls were capable of achieving.

The impact that scientific and technical development is making in Britain's industrial life was emphasised by Lord Mills, H M Paymaster General, when he opened the exhibition. He looked to the great manufacturing industries to benefit from the progress that was being made in the automation field to increase their efficiency. Lord Hailsham, Minister for Science, held a similar view, adding 'Nothing can be more important for the application of scientific discoveries to our industrial life than that managements should be able to see for themselves the vast range and ingenuity of instruments and control devices now available to them. This exhibition is an excellent means of promoting that knowledge'.

The exhibition was promoted by the British Electrical and Allied Manufacturers' Association, the British Industrial Measuring and Control Apparatus Manufacturers' Association, the British Lampblown Scientific Glassware Manufacturers' Association, the Drawing Office Material Manufacturers' and Dealers' Association, the Electronic Engineering Association, and the Scientific Instrument Manufacturers' Association of Great Britain. Among the exhibits were data processing equipment for solving research, production or management problems; control equipment for continuous or discontinuous manufacturing processes; instruments ranging from simple meters to the most sophisticated electronic supervisory equipment; and materials and components for developing all such types of equipment. Here are brief descriptions of some typical exhibits.

Meter Development

Noticeable trends in meters displayed were the development of further standardised types suitable for compact arrays, and the parallel development of more complicated instruments in which automatic scanning over a number of points removes the need for numerous dials. In both cases the trend towards miniaturisation was apparent.

Crompton Parkinson Ltd showed their new miniature circular-scale moving-iron meters, available in ranges up to 0–30 A and 0–300 V. Scale lengths of $3\frac{1}{8}$ and $4\frac{1}{4}$ in (79 and 108 mm) are achieved on dial diameters of 2 and $2\frac{1}{2}$ in (51 and 63 mm). They are available in three types of case: moulded plastics, die-cast metal, and sealed shock-proof. Another type of circular scale instrument shown by the company—the 'New World' range—is designed to give clear visibility over a wide viewing angle. The dial lies in the same plane as the front of the bezel, and the anti-parallax platform scale can be read accurately from an acute angle. Light striations across the dial are prevented by the moulded glass cover of the instrument.

A precision electrostatic voltmeter, full-scale deflection 1 000 V, was exhibited by Nalder Bros and Thompson Ltd. Normally the torque-weight ratio of this type of instrument is low, and electromagnetic instruments have been preferred for sub-standard transfer work in spite of the fact that they absorb power and have a restricted frequency range. However, Nalders have achieved a remarkably low pivot friction and a high torque-weight ratio in their 12 in (30·5 cm) instrument. Consequently, a precision voltmeter with an accuracy better than $\pm$ 0·3 per cent is now available, having an input resistance of nearly 20 million megohms. It measures direct or root mean square voltages and its scale is substantially linear above 300 V.

The development of digital instruments to replace conventional pointer meters in certain situations continues, and on the stand of Marconi Instruments Ltd a type 1325 digitiser was shown, indicating the value of applied d c potentials from 0·000 to 0·999 V. This is a fully transistorised analogue-to-digital converter and can be used to feed indicating, recording, or processing equipment. An industrial analogue-to-digital converter was also shown by Evershed and Vignoles Ltd. In addition supervisory control equipment was displayed, each basic set providing 40-point telemetering facilities of analogue and supervisory signals, and facilities for 40 control functions in the reverse direction, all over one pair of lines.

Packaged Electronics

A feature of the electronic equipment displayed at the exhibition was the growing use of plug-in sub-assemblies as an economic alternative to producing large general-purpose equipment. The new oscilloscope produced by Cossor Ltd, for example, has plug-in Y amplifiers and time-base units. Use of the different units permits a Y amplifier coverage from 0 to 60 Mc/s, and time-base speeds from 0·1 cm/sec to 50 cm/μsec.

The packaged concept of electronic equipment was also well exemplified by the 'Datapacs' displayed by the English Electric Co Ltd. The company considers that equipment for data reduction, computation, and control in industry is developing rapidly and must be capable of easy expansion on a modular basis. 'Datapacs' are in the form of small plug-in units which can be built up into

computer logics and units such as line printers or analogue-to-digital converters.

Two distinct types of circuit logic have been developed. The 'Telpac' units have been designed for special-purpose computer applications and have a single type of package. A prototype computer using these has been built. The other type, 'Atelpacs', is a range of logical elements developed in the first instance to fulfil a requirement for static switching units for applications such as counting, sequencing, and gating in general data-handling systems.

Packaged Unit Applications

A two-cubicle arrangement of 'Datapacs' has been produced for the control of a steel mill hot saw bench. This aims at minimising the waste which occurs in cutting roll bar to customers' requirements, the difficulty being that the length of the hot bar emerging from the mill is not known until it reaches the saw. Investigations with a general purpose D E U C E computer showed that an increase of between 1 and 5 per cent in the yield currently achieved by a good saw clerk should be possible, and a special purpose computer was subsequently built up. Its main features are that only the minimum storage and arithmetic facilities required for the job are used. Other applications for which similar special purpose computers built up of plug-in units are being considered, because of the economies they show over general purpose machines, include control of remote circuit-breakers, of a kinetic heating simulator, of a pipeline, and of a barrel-filling process.

Building-bricks for the construction of electronic control systems were also displayed by Mullard Equipment Ltd: 'Combi-elements', which provide a comprehensive set of digital circuit units; 'Norbits', for the construction of industrial sequencing controls; conventional and programmed counters; and ancillary units for industrial counting and batching systems. Projects under investigation for application of these units include transfer-line controls, safety, and testing equipment.

The basic 'Norbit' unit is a transistor switching element which, for simplicity and flexibility, has been designed for use as an AND or an OR circuit, depending on the way it is connected. On the receipt of information from the limit switches of the machine under control, the unit performs the necessary logical operations and delivers signals in the correct sequence to a suitable output unit, which in turn activates the transducers governing or monitoring the functions of the machine. The basic unit measures $2\frac{1}{2}$ by $1\frac{9}{16}$ by $\frac{1}{2}$ in (63 by 40 by 13 mm).

'Combi-elements', which include flip-flops and other multi-vibrator circuits, pulse shapers, gate circuits, and amplifiers, are hermetically sealed in small plastic cases measuring 2·1 by 0·94 by 0·39 in (53 by 24 by 10 mm), designed for quick and easy mounting on a printed circuit board by the techniques usually employed for mounting resistors and capacitors. The range of circuits has been based on the principle of d c gating, and in general the signal transfer from element to element is at d c levels. The flip-flops and other multi-vibrators can be triggered either by a d c signal or by a voltage step (a c signal).

Several standard sub-chassis assemblies for reading up to four digitisers of either the binary or decimal type, together with standard decimal decoders, were shown by the General Electric Co Ltd. The use of a small number of such blocks enables many different digitiser systems to be built up. On display was an altitude encoder system, using digitisers, developed for the Ministry of Aviation. It will transmit an aircraft's altitude automatically to an air traffic control centre on command, and will thus play an important part in expediting the movement of aircraft on congested airways, when standards for such equipment have been internationally agreed. In the G E C unit, height information over the range 5 000 to 32 000 ft (1 500 to 10 000 m) is provided in the form of a six-digit cyclic binary code.

Extreme reduction in the size of circuit packages was displayed on the stand of the Ministry of Aviation. The Royal Radar Establishment, Malvern, has under way a programme of research aimed at establishing techniques for use in micro-miniaturised transistor circuits, the immediate objective being to scale down conventional transistor circuits by at least 10:1 in both size and weight. As far as possible, inorganic materials are used. At present the circuit substrate is glass, but ceramic is preferred and will be used if material with a sufficiently smooth surface can be developed. This requirement arises because components are in the form of thin films deposited by vacuum evaporation.

Resistors consist of nickel-chromium films about 75 Å thick, which are processed to give values up to 100 000 ohms in an area 5 mm square. Capacitors are made up in the form of a sandwich of thin metal films on each side of a magnesium fluoride film dielectric, a capacitance value of 2 000 pF at 25 V d c working being obtained in an area 5 mm square. Semiconductor elements are fabricated in the form of flat units using commercially available types.

Semiconductor Devices

Many stands gave evidence of the growing range of semiconductor devices—more types, greater frequency coverage, higher powers. The potentialities of the alloy diffusion technique have been developed by Mullard Ltd along a number of different lines, to provide germanium transistors for a variety of computing and industrial applications as well as for more advanced tele-communications purposes. The type AFZ11 has been developed for amplification at 100 Mc/s, at which frequency it gives a power gain of greater than 10 dB, the noise figure at the same frequency not exceeding 6 dB. A transistor operating at twice this frequency will be available soon.

Also exhibited by Mullards were a transistor for future computer applications at clock pulse rates of up to 10 Mc/s, a transistor for driving high-speed ferrite memory systems in computers (capable of delivering output pulses of several hundred mA with very fast rise times, the value of the f_t parameter being greater than 60 Mc/s), and a p-n-p-n switching transistor for use in flip-flop astable and monostable circuits in place of the two three-layer devices normally required. An avalanche transistor capable of reaching a peak current of 50 mA with a rise time of only 1 millimicrosecond was also exhibited.

The range of tunnel diodes produced by Standard Telephones and Cables Ltd has been extended from two to six, and typical resistive cut-off frequencies extend up to 130 Mc/s. Another new product by the company, closely allied to these diodes, is the so-called 'backward'

rectifier. A very low voltage drop (200 mV) makes this device suitable for magnetic core switching circuits and for use in conjunction with tunnel diodes. Silicon variable-capacitance diodes for use in parametric amplifiers and similar devices at frequencies up to the S-band were displayed by the General Electric Co Ltd, in addition to three other variable capacitance diodes designed for use in automatic frequency control and frequency modulation. Two low temperature-coefficient silicon reference elements—coefficients at breakdown of less than 0·01 and 0·001 per cent per deg C—are also being made.

Westinghouse Brake and Signal Co Ltd showed a number of control applications for their 'Trinistors'. The outstanding property of this device, a silicon controlled rectifier, is its ability to control several kilowatts of power while requiring only a few milliwatts of control power itself. A 1 kW single-phase inverter demonstrated how two of the devices could be used to provide power for a mobile lighting system. The parallel inverter circuit employed generates 1 kW of a c power at 240 V, 1 000 c/s, for a nominal 24 V d c input. Its full-load efficiency is 85 per cent and when used to supply a bank of twelve 80 W fluorescent tubes an improvement in tube efficiency by about 15 per cent is obtained.

Semiconductor devices manufactured by Joseph Lucas Ltd are being marketed by G & E Bradley Ltd, an associate company. Among new additions to the Lucas range are high-power silicon diffused junction rectifiers designed to give forward current ratings of up to 100 A, and Zener and clipper diodes operating at nominal voltages between 6·8 and 33 V. Power transistors were also shown by A E I (Woolwich) Ltd, two of the range having peak current ratings of 10 A at collector-base ratings of 80 and 100 V. A range of three germanium n-p-n devices for complementary switching circuits is also being produced.

Transistorised Computers

Among the computers exhibited were the transistorised Sirius and Argus machines produced by Ferranti Ltd. Sirius is a desk-size computer that works straight off a normal 230 V, 50 c/s, 5 A supply. Storage is provided within it by long delay-lines holding 1 000 words. An indication of the capacity of the machine is gained from the fact that 27 simultaneous equations can be solved in six minutes.

The Argus computer has been designed for real-time control of a variety of industrial processes of the type requiring many parallel input and output channels. It has transistorised circuitry and a ferrite core memory of 1 024 words; programmes are set up on peg-boards held in removable trays.

The possibilities in using computers to run a factory in the optimum state were suggested by a display on the stand of Elliott Brothers (London) Ltd. There the transistorised 'Optimat' controller was shown optimising the functioning of an oil refinery distillation column (represented on the stand by an analogue computer). By making a series of small changes in the parameters of the system under control and adopting only those that show an improvement, the machine reaches the optimum conditions for the process. Simple as the technique appears, it is likely to have an enormous impact on industry in the future, and will play a major part in the development of automation.

Statistical Year Book of the World Power Conference (No. 9)

NOWADAYS, access to comparable international power statistics is taken as a matter of course, and it is difficult to visualise a time when they were not easily available. Nevertheless, such was the case 25 to 30 years ago, as the issue of the latest Statistical Year Book serves to remind us. It was in 1926 at a W P C Sectional Meeting in Basle that a resolution was first adopted on the need to prepare power statistics on a comparable basis, and although some time passed before satisfactory data could be issued (since agreement on a common basis was no easier then than it is now), the arduous task of definition and compilation has been continued ever since. The first Year Book appeared in 1936, covering the years 1933 and 1934; the most recent has just been published for the years 1954-1957, with supplementary later figures where possible.

The announcement, therefore, that this latest Statistical Year Book will also be the last in the series provides an occasion not only for paying tribute to all the hard work put into their production, but also to acknowledge the debt owed to the original sponsors of the project for the initiative, foresight and energy which they brought to bear on a difficult pioneering effort.

The B E A M A has perhaps a special interest in the Year Book since the early days of the World Power Conference owed much to the inspiration of the late Mr D. N. Dunlop, B E A M A's first Director, and in fact the first Year Book was issued from 36 Kingsway, London, W C 2.

In future the Statistical Office of the United Nations will collect and publish annual statistics on fuel and power, although this does not mean that this particular field is being entirely abandoned by the World Power Conference. It is intended to start work on a new series of surveys containing authoritative estimates of energy resources accompanied by an editorial commentary. The first survey will be published for the Sixth (Plenary) World Power Conference to be held in Melbourne in October, 1962, and subsequent issues will be published at intervals of six years. These surveys will clearly be of considerable value.

It only remains to say that the familiar green cover backs the last issue of the Year Book, which follows the same style and layout of earlier issues. Regular inquirers will have no difficulty in turning immediately to the particular information they require. The Electricity and Water-Power Section covers a large number of countries in this issue, some in more detail than before, and the number of pages of this section takes up ten pages more than in the previous issue.

Book Reviews

Basic Technical Electricity. *By H Cotton.* $7\frac{1}{2} \times 5\frac{1}{4}$ *in* (190 × 133 *mm*). *Pp* 246. *Illustrated*. (*London: Cleaver-Hume Press Ltd*, 1960). Price 12s 6d net.

This is the introductory volume of the Cleaver-Hume Electrical Series, which consists of ten works by specialised authors. Now in its third edition, this volume has been revised and uses the metre-kilogram-second system. This has meant rewriting the chapter on units and bringing forward to this chapter other similar matter which was formerly at the end of the text. The original feature of introducing the subject from the structure of the atom has been retained.

To help in giving a clear understanding of the fundamentals of electricity there are worked examples, and easy experiments are described which can be performed with simple apparatus. This electrical series has become a very popular source of information, particularly to the student and to those who need only a broad general knowledge of the subject.

Electrical Trade Directory. $9\frac{1}{4} \times 6\frac{1}{2}$ *in* (235 × 165 *mm*). *Pp* 1712. (*London: Benn Bros Ltd*, 1960). Price 63s net.

Better known as the 'Blue Book', this reference work is now in its 78th year. It aims at providing in one volume an accurate and comprehensive source of information on the electrical industry and allied trades in the U K. There are eleven main sections which cover manufacturers, contractors, wholesalers, importers, exporters, engineers, public utilities and associations.

Perhaps the most widely used sections are the lists of products and materials, which give the suppliers of some 2 600 items. Another very useful section is the list of 7 000 patented and trade names of electrical and allied products.

This directory should be a very useful addition to the reference library of engineers, buying agents and users of the products and services of the electrical industry.

Metal Industry Handbook and Directory. $8\frac{1}{2} \times 5\frac{7}{8}$ *in* (216 × 149 *mm*). *Pp* 584. (*London: Iliffe & Sons Ltd*, 1960). Price 20s net.

This handbook is recognised throughout the world as a standard source of reference for non-ferrous metals. It has four main divisions. The first deals with the properties of metals and alloys, but it also includes a list of proprietary names of alloys, British Standards for non-ferrous metals, and government departments' specifications and test requirements. The second division is mainly taken up by general data and tables, while the third part deals with electroplating and allied processes. The last division contains a directory of manufacturers, trade and technical associations, a buyers' guide and a list of trade names.

British Plastics Year Book. $9\frac{1}{2} \times 6\frac{1}{4}$ *in* (235 × 159 *mm*). *Pp* 696. (*London: Iliffe & Sons Ltd*, 1960) Price 42s net.

The publishers claim that this is the only guide to the plastics industry and its manufacturers and products published in the U K.

All the contents have been brought up-to-date and it now contains some 7 000 names and addresses of British and overseas manufacturers and other organisations connected with the plastics industry. Other useful information is classified in lists of products, materials and plant, and a list of trade names which is world-wide. The glossary of technical terms and technical and general data applicable to the plastics industry are other features which are of great value.

Glossary of Atomic Terms. $6\frac{1}{4} \times 4\frac{1}{8}$ *in* (159 × 105 *mm*). *Pp* 54. *London: H M S O*, 1960). Price 3s 6d net.

So rapid is the advance in nuclear technology that this is the second revision of the 'Glossary of Atomic Terms' since its original publication in 1958.

Compiled primarily for the benefit of the many non-technical readers whose work brings them into contact with this subject, this book gives in simple language the meanings and explanation of some 500 terms which are in common use in the nuclear energy fields. As well as purely technical terms, the list includes the code names given to reactors and the geographical locations of the various nuclear power and research establishments.

Principles of Alternating Currents. *By W. Sluckin and J. R. Greener.* $7\frac{1}{2} \times 5$ *in* (190 × 125 *mm*). *Pp* 338. *Illustrated. Index*. (*London: Cleaver-Hume Press* 1959). Price 15s net.

Now in its second edition, and one of the publisher's electrical series, this work has been revised to bring it in to line with the MKS system. The first five chapters are mainly concerned with explaining the basic principles of alternating currents and circuits. Resonance is particularly well defined, using as analogy mechanical oscillatory systems.

Transformers and power transmission are the subject of the next four chapters, including one on power factor correction. The next chapter deals with ac measurement with the thermal junction ammeter, the latter being covered more fully at the expense of the hot-wire instrument which is only briefly mentioned. The chapter on electronics deals mainly with rectifiers, amplifiers and oscillators, with a description of the cathode-ray oscilloscope. The final chapter is a review of some alternating current circuits and this is followed by test questions and answers.

The subject of a c rotating machines has wisely been omitted, as this as a subject of another of the books in the series. The book is intended for formal studies leading to the national certificate and City and Guilds certificates and the reader is not expected to have more than simple mathematics and elementary electrical knowledge.

A Simple Approach to Electronic Computers. *By E H W Hersee.* $7\frac{1}{2} \times 5$ *in* (191 × 127 *mm*). *Pp viii* + 104. *Illustrated. Index*. (*London: Blackie & Son Ltd*, 1959.) Price 12s 6d net.

In writing this little introductory book the author has in his own words 'tried to present in some detail, and as simply as possible, a few of the basic working principles of both digital and analogue machines' with, we may say, remarkable success. It is offered as an introduction to more advanced text books and it meets that need; it can easily be read with profit, however, by anyone who wishes to know how computers work.

The chapter headings give a good idea of the scope of the book and they are as follows. Number representation in digital computers (dc's); basic circuits in dc's; memory or store; control; input and output; the dc at work; special-purpose dc's; analogue computers (ac's); basic circuits in ac's; and the solution of a simple problem by an ac.

Throughout the book the author gently leads the reader along by easy stages so that when the end is reached one feels reasonably well equipped for reading the more voluminous and detailed works on computers and their wide and varied applications. The book soundly disposes of the stupid term 'electronic brain' which, it is cogently remarked, has been applied to machines which are essentially 'simple-minded'. That description could as well be applied to the originators of the term!

S A S

Modern Electronic Components. *By G. W. A. Dummer.* $8\frac{3}{4} \times 5\frac{3}{4}$ *m* (222 × 146 *mm*) *Pp* 472. *Illustrated. Index*. (*London: Sir Isaac Pitman & Sons*, 1959). Price 55s net.

This book presents the first comprehensive survey of the more generally used electronic components. It includes information on component behaviour under all conditions of service and gives a first class summary of essential data. It should be of very great value to the electronic engineer in selecting suitable components for a particular purpose.

Foundations of Electrical Engineering, Vol II. *By H Cotton and E W Golding.* $8\frac{3}{4} \times 5\frac{3}{4}$*m* (222 × 146 *mm*). *Pp* 252. *Illustrated. Index*. (*London: Sir Isaac Pitman & Sons*, 1959). Price 20s net.

This series of books, the first volume of which was published in 1952, is designed mainly for students taking ordinary national certificate courses. Volume II deals with alternating current circuits and machines, and the MKS system is used.

Linear Network Analysis. *By S Seshu* and *N Balabanian.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xiv* + 571. *Index. Illustrated*. (*London: Chapman & Hall*, 1959.) Price 94s net.

Still another network book? Well, yes and no ! In the sense that it does deal with electrical networks, then 'yes' is the answer. By the implication that 'still another' might be deemed to bear—that of containing no essentially new matter—then again we can say 'yes', as do the authors themselves. But in the manner of treatment the book has

much novelty, and both heuristically and pedagogically it escapes the restrictive qualification with which this review opens.

The work covers both active and passive networks and it ranges from elementary fundamentals to 'the thresholds of some of the most advanced concepts in network theory'. In developing the foundations of network theory the authors have, in particular, endeavoured 'to smooth out the transitions among (*a*) steady-state and transient responses, (*b*) time and frequency responses, and (*c*) analysis and synthesis'.

Chapter 1 gives fundamental equations, while Chapter 2 reviews elementary network theory, introducing the complex plane in relation to simple loop and node systems of equations. Chapter 3 discusses the elementary aspects of matrix algebra and network topology, and Chapter 4 completes the routine analysis of networks. Chapter 5 deals with the more important network theorems and relates steady state and transient responses. Chapter 6 presents the superposition integral representation for the response function, and Chapter 7 discusses network functions in the complex frequency plane.

Chapter 8 gives a classical treatment of two-port parameters, including scattering parameters. Chapter 9 deals with analytic properties of network functions and it includes the topological formulae of Kirchhoff and Maxwell. Chapter 10 covers feedback and related topics, among which are signal flow graphs, the Nyquist criterion of stability, and the root locus. Chapter 11 gives a generalised treatment of classical filter theory based on image parameters. An appendix provides a number of topics connected with functions of a complex variable and Laplace transforms which serve as the necessary background to the subject matter of the book.

A useful bibliography is provided and there is the usual index. The book is well and amply illustrated and problems for solution are given at the end of each chapter.

Quite apart from the general excellence of this work we commend the extensive use that has been made of matrices and topology. There is a growing need for instruction on the practical applications of these two branches of mathematics to the solution of engineering problems, so that the expositions given by the authors are very welcome. The production of the book is, of course, above criticism and it is one that we can recommend without question to all classes of electrical engineers interested in network theory.

S AUSTEN STIGANT

Symmetrical Components Applied to Electric Power Networks. *By G O Calabrese.* 9 × 5¾ *in* (229 × 146 *mm*). *Pp vii* + 464. *Index. Illustrated.* (*New York: The Ronald Press Co.*, 1959.) Price $12.00 net.

There ought to be available some high professional award to writers of outstanding scientific and technical books of the sort that contribute prominently to superior knowledge. If there were such a distinction, the author of this book would be a worthy candidate for nomination, for his work has all the requirements needed for special recognition. While the preface indicates that the book was written solely with the object of familiarising students and practising engineers with the theory of symmetrical components and of supplying an up-to-date discussion of the fields in which the theory is applied, it does so in such a comprehensive and thorough manner that the book can almost be regarded as breaking new ground. In fact, we are inclined to believe that the author has served his readers far better than perhaps he realises.

The first five chapters are introductory in character and cover certain fundamentals: network equivalence, per unit and per cent quantities, calculating boards, and circuit theorems. Chapters then follow on the mathematical theory of symmetrical components for three-phase circuits, the application of symmetrical components to three-phase circuits, and the analysis of three-phase symmetrical systems with one fault or unbalance. Broadly, these cover unfaulted unsymmetrical circuits, circuits having unbalanced loads, short-circuits to earth or between phases, open circuits, and certain combinations of these. The chapter on systems with one unbalance is particularly good because it shows how the sequence networks are interconnected for the different kinds of unbalance or faults and the reasons underlying such interconnections; in fact, a 'philosophy' of sequence networks. It may be said however that a few examples of more complicated networks dealt with on similar lines would have been very helpful—a minor criticism perhaps, but an important matter !

The next three chapters deal respectively with circuit R, L, C, Z parameters to currents of positive, negative and zero phase sequence; they are impedances of three-phase transmission lines, capacitances of transmission lines, and impedances of cables. Single and multiple circuit overhead lines with and without overhead earth wires are included. The chapter on cable impedances covers single core and multicore cables but it could usefully have been made much more complete.

The last chapter is on the zero, alpha, and beta components devised by Edith Clarke, about which more extensive information will be found in Professor Clarke's two-volume work 'Circuit Analysis of AC Power Systems'.* Being primarily a students' text, the book contains numerous problems for solution and these are largely of a practical nature. The work is exceedingly well illustrated; it could hardly have been written more clearly, and it is very well printed.

Designers of power equipment, relay protective schemes, and power networks, as well as those engineers responsible for the satisfactory operation of power systems and the investigation of fault conditions on systems, will be very grateful to the author for this most excellent work. It is the outcome of many years of practical and teaching experience of the subject and it shows the extent to which the theory and practice of symmetrical components have developed since the appearance of Fortescue's original AIEE paper in 1918.

* THE BEAMA JOURNAL, **51,** No 87, p 303; **59,** No 175, p 121

SHORTER BOOK REVIEWS

Semiconductors. *Edited by N B Hannay.* 9½ × 6½ *in* (241 × 165 *mm*). *Pp xxiii* + 767. (*New York: Reinhold Corporation; London: Chapman & Hall*, 1959.) Price 120s net.

A study of fundamental physics and the physical chemistry of semiconductors, with a detailed analysis of the most important materials.

Basic Physics of Atoms and Molecules. *By U Fane and L Fane.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp xv* + 414. *Illustrated.* (*New York: John Wiley; London: Chapman & Hall*, 1959.) Price 80s net.

This presentation of Quantum Physics does not require an extensive knowledge of physical theory or mathematics. Concepts and laws are established by inductive analysis of experiments and then formulated into mathematical language.

Atomic Age Physics. *By H Semat and H E While.* 8 × 5¼ *in* (203 × 133 *mm*). *Pp vii* + 230. *Illustrated.* (*New York: Reinhold; London: Chapman & Hall*, 1959.) Price 16s net.

Based on a course of atomic physics broadcast on the NBC TV network, this book is of an elementary nature and is intended for reading by the general public.

Elementary Mathematical Programming. *By R W Metzgen.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp ix* + 246. *Illustrated.* (*New York: John Wiley; London: Chapman & Hall*, 1959.) Price 48s net.

Intended for the reader with a limited background in mathematics who is interested in the basic techniques and applications of mathematical programming.

Circuit Theory of Linear Noisy Networks. *By H A Hans and R B Adler.* 9¼ × 6 *in* (241 × 152 *mm*). *Pp xii* + 79. *Illustrated.* (*New York: John Wiley; London: Chapman & Hall*, 1959.) Price 96s net.

A study of amplifier performance and noise with a consideration of various ways of achieving low noise limits.

Statistical Quality Control. *By D H W Allan.* 7½ × 5 *in* (191 × 127 *mm*). *Pp x* + 129. *Illustrated.* (*New York: Reinhold*, 1959.) Price 28s net.

Written for the executive who wishes to study statistical quality control without the need to have a mathematical background.

Scientific Russian. *By G E Codogannis.* 6½ × 5¼ *in* (165 × 140 *mm*). *Pp xii* + 225. (*New York: John Wiley; London: Chapman & Hall*, 1959.) Price 28s net.

Intended for engineers, students and others who need to have a working knowledge of Russian to cope with technical matter published in that language.

Work Measurement. *By V H Rotroff.* 7½ × 5 *in* (191 × 127 *mm*). *Pp* 198. *Illustrated.* (*New York: Reinhold*, 1959.) Price 39s net.

This book presents the fundamental principles and techniques of work measurement and their practical application to modern industry.

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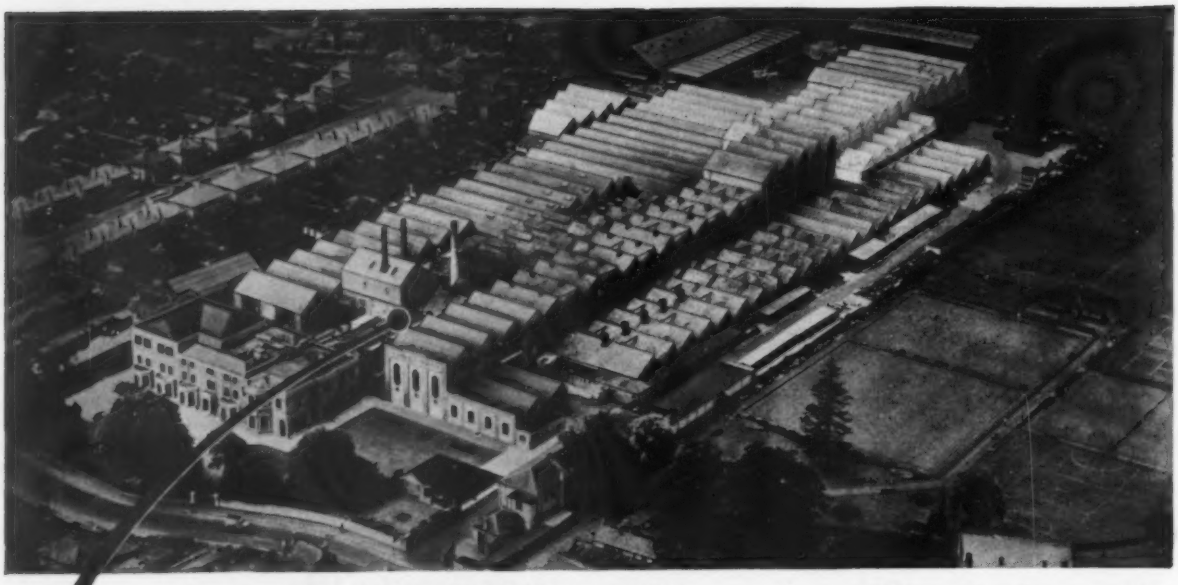

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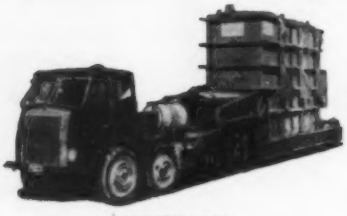

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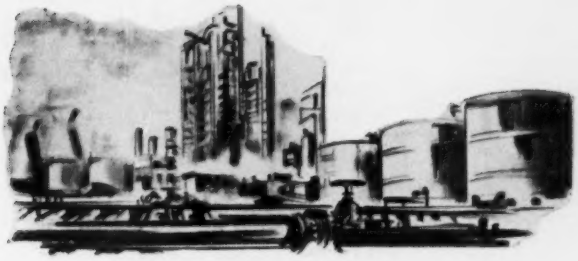

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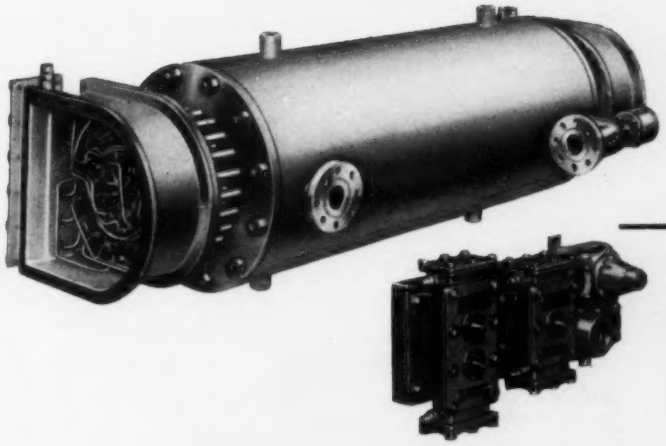

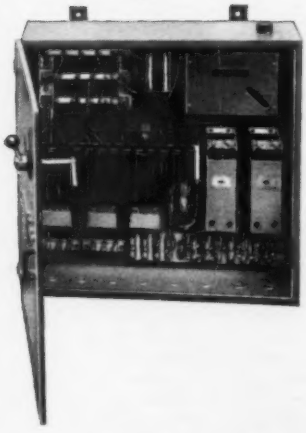

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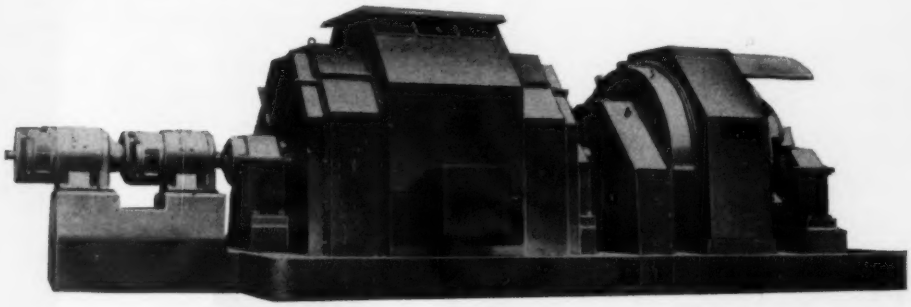

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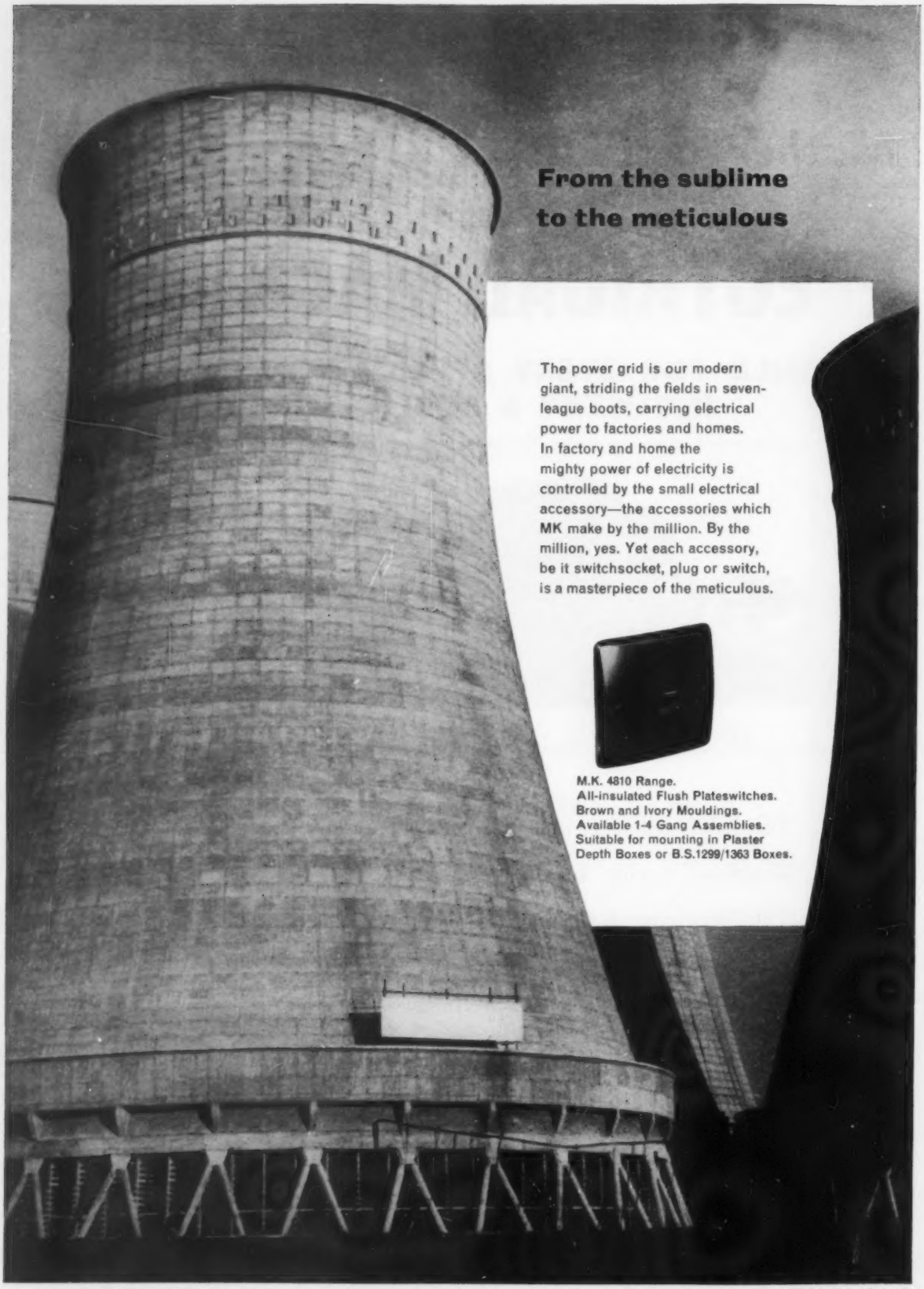
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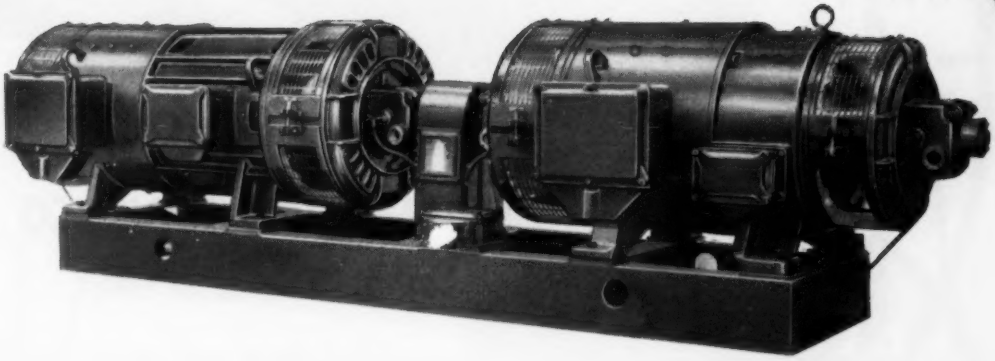

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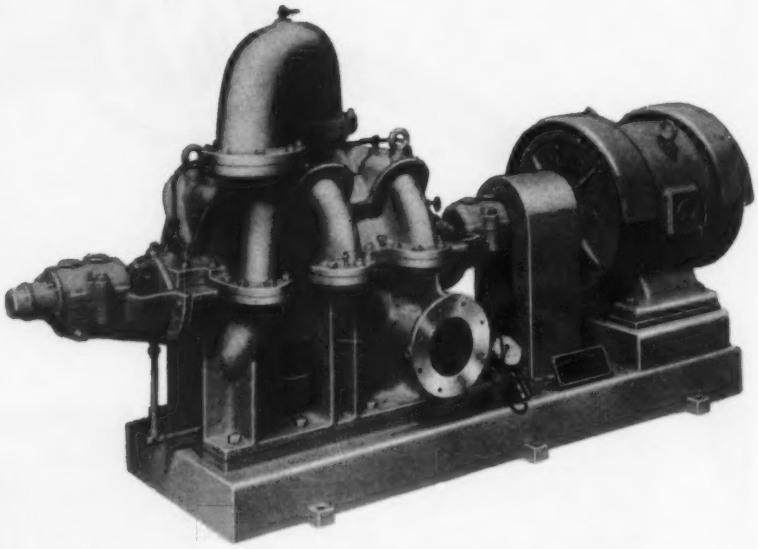

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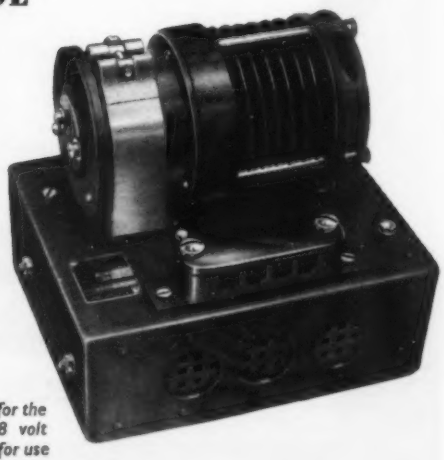

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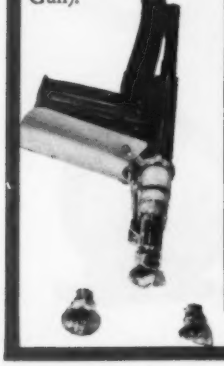

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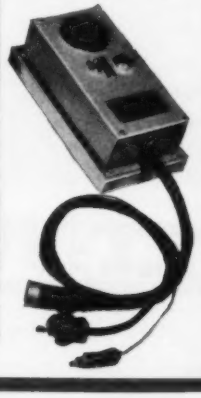

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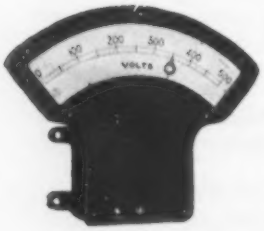

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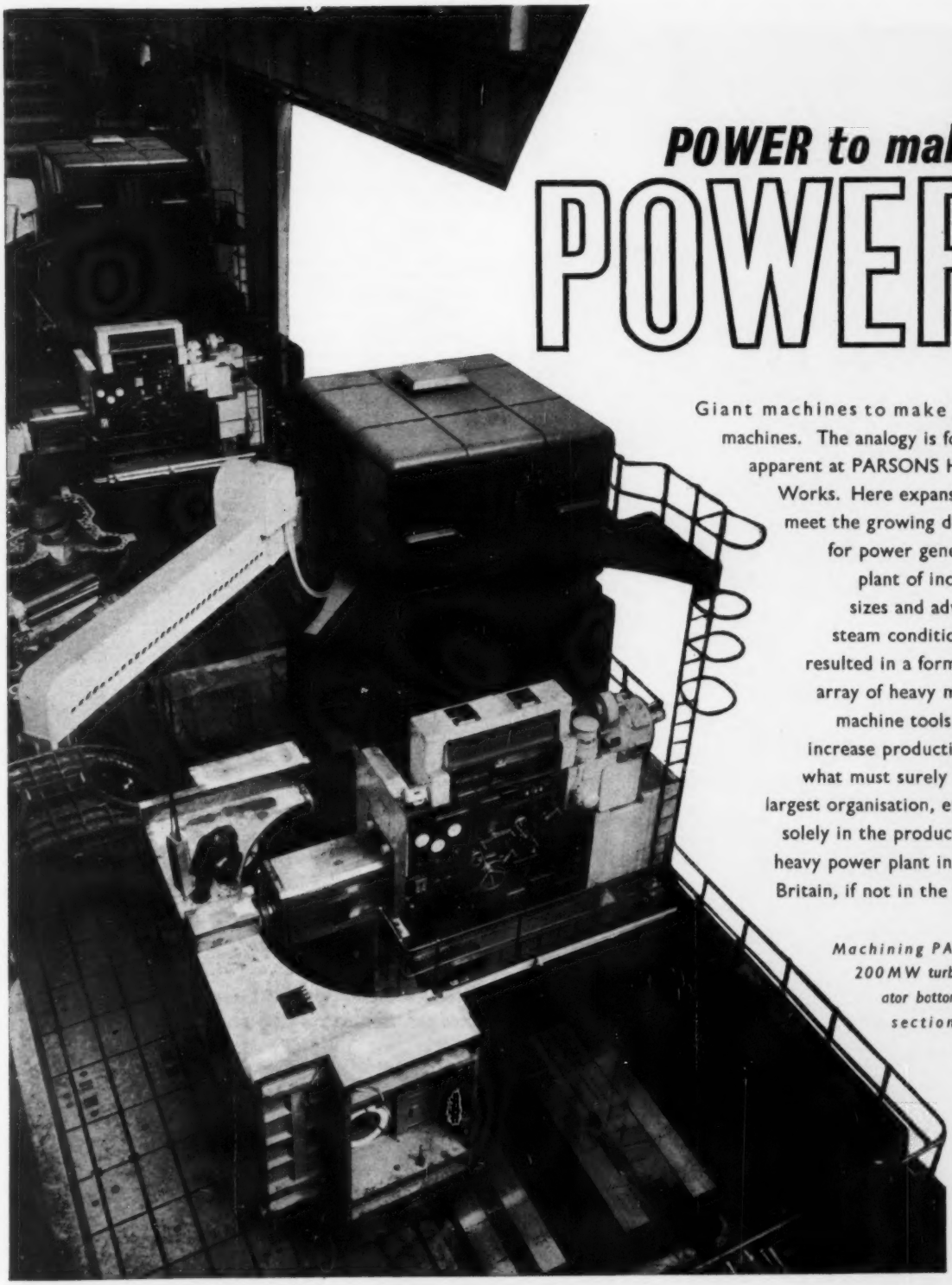

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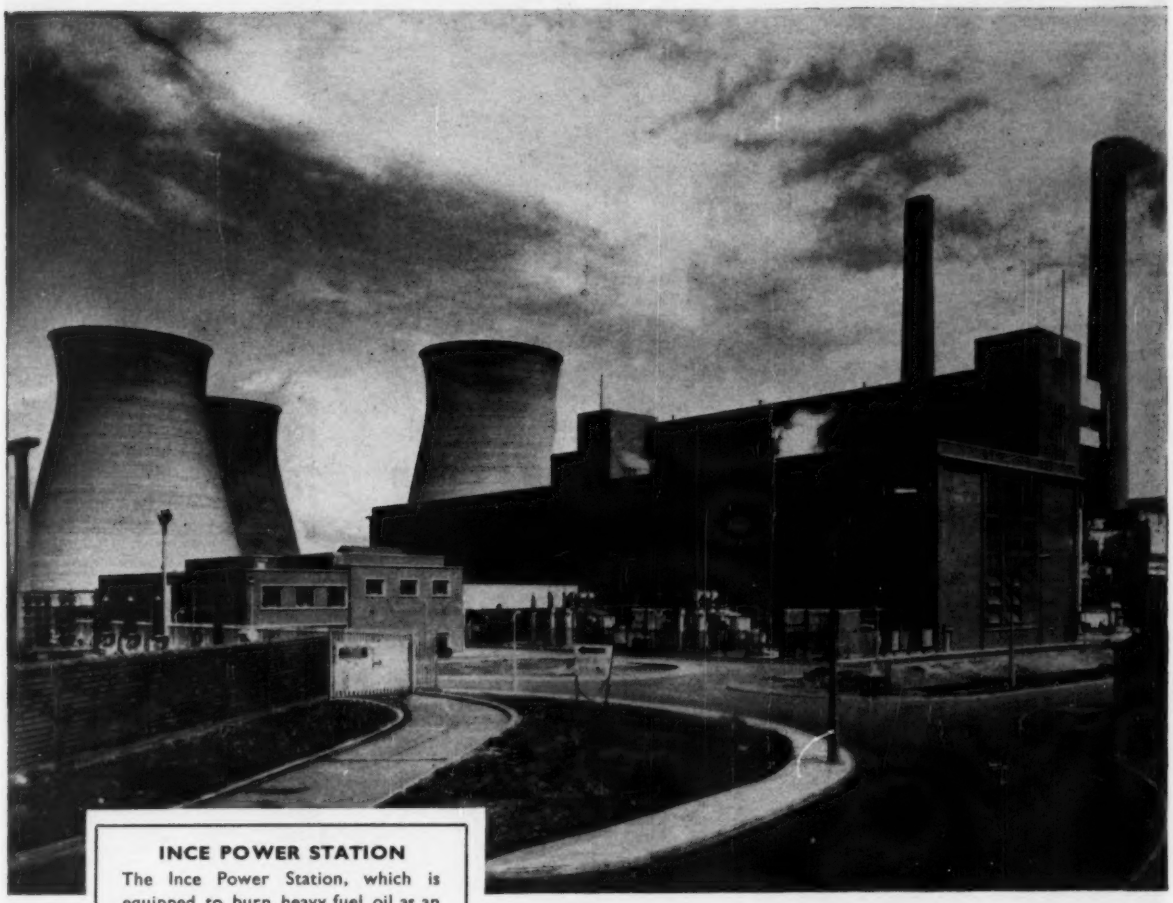

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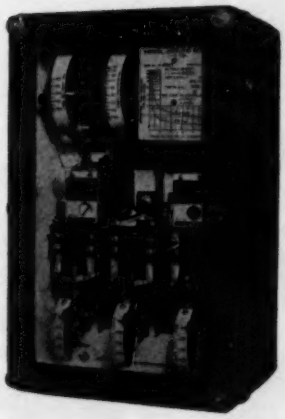

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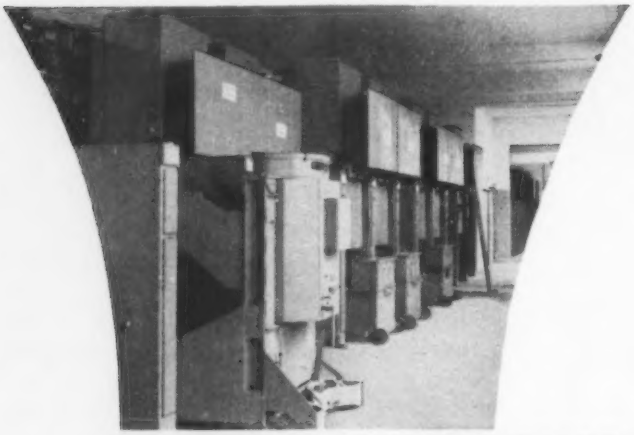
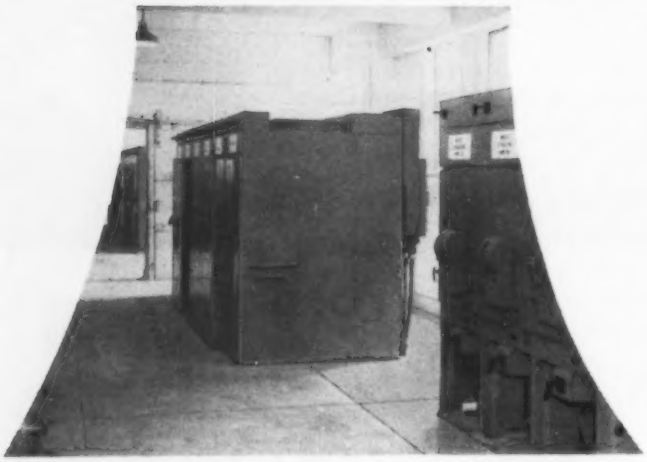


POWER STATION SWITCHGEAR IN SOUTHERN RHODESIA



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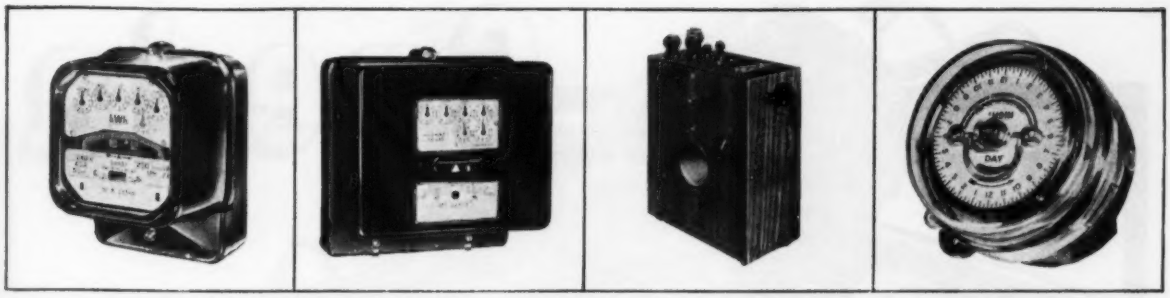

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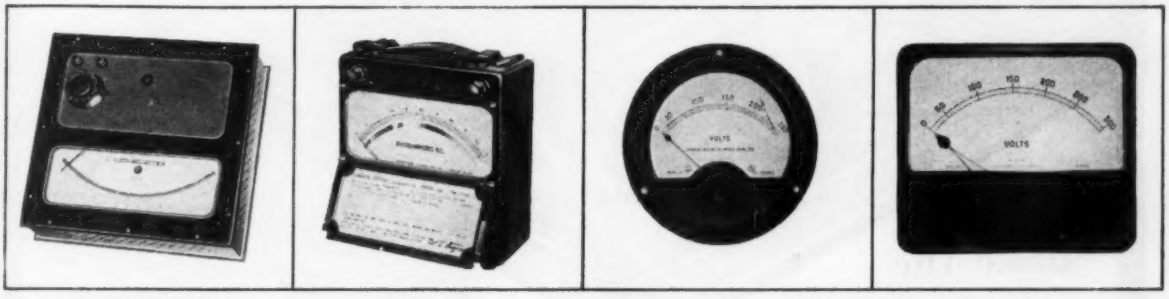

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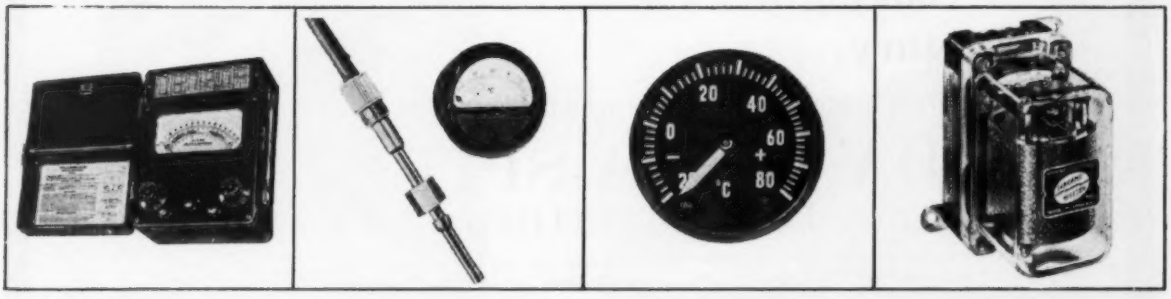

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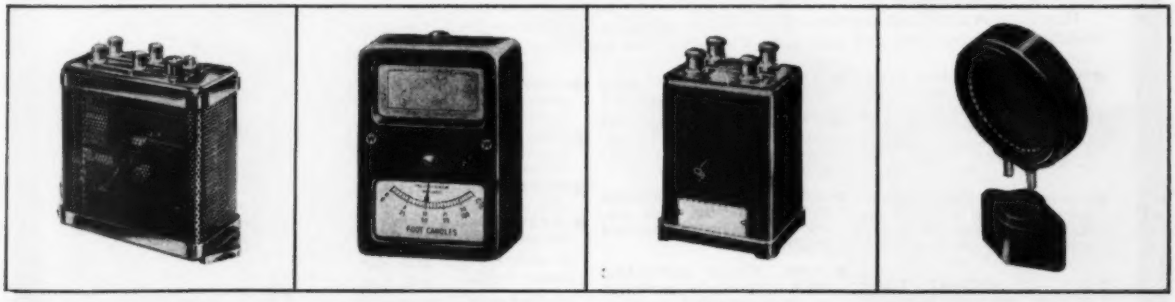

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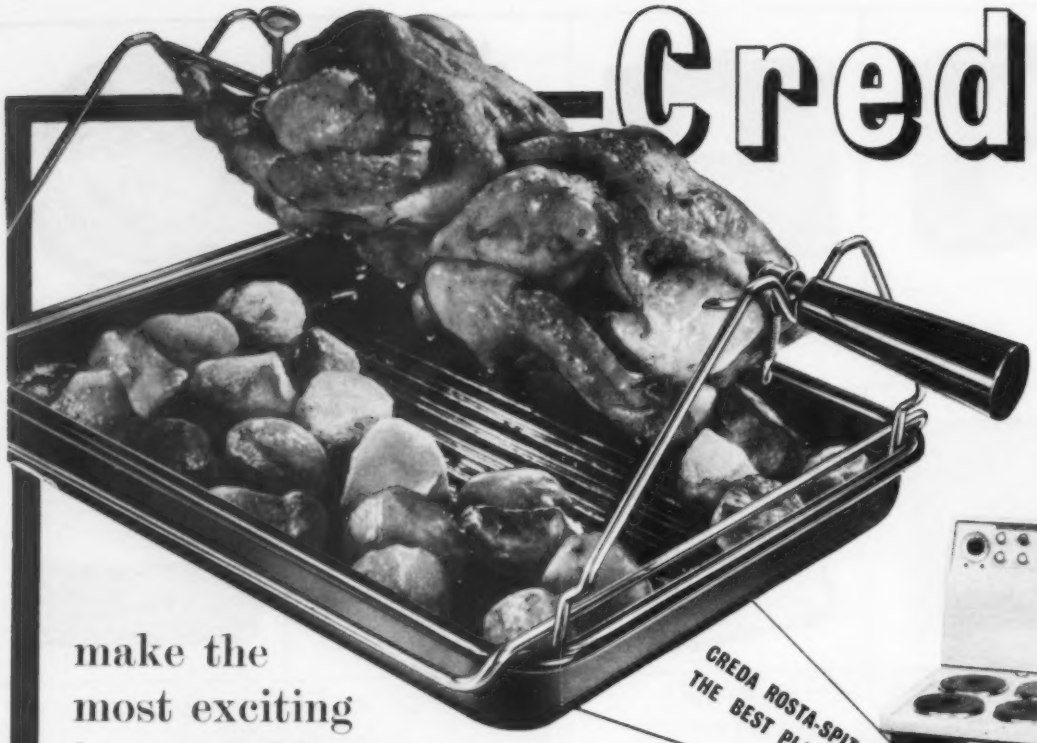

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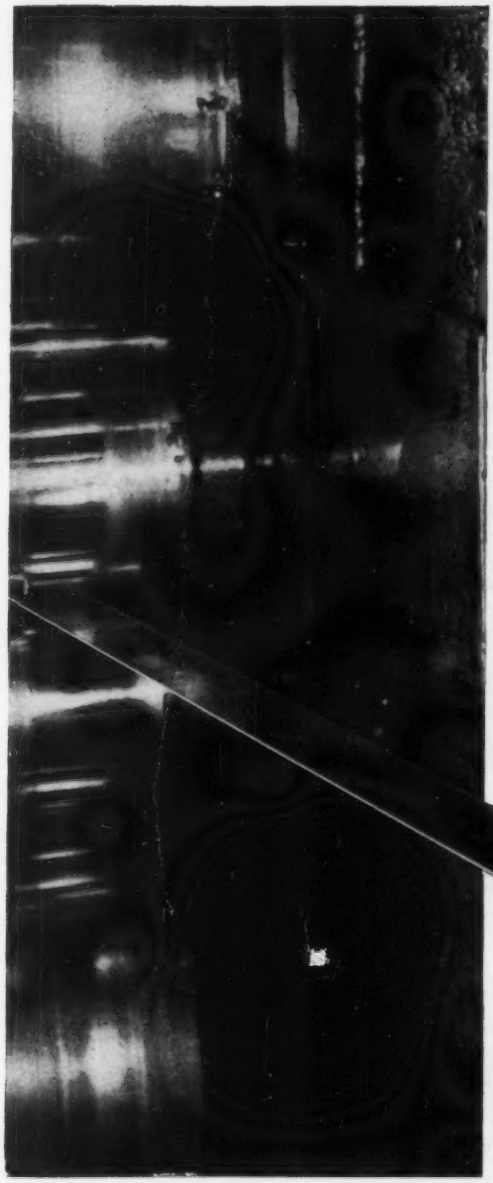

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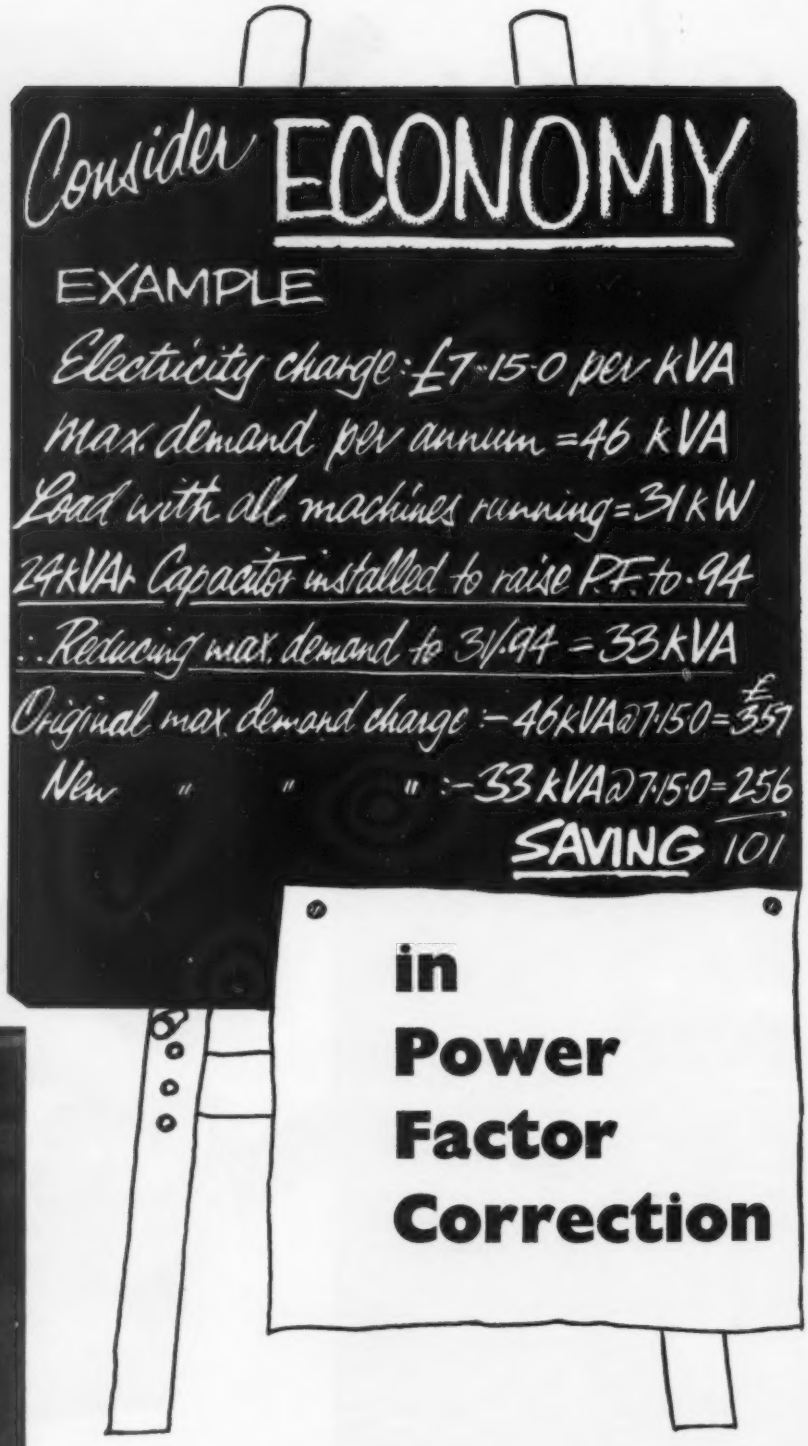
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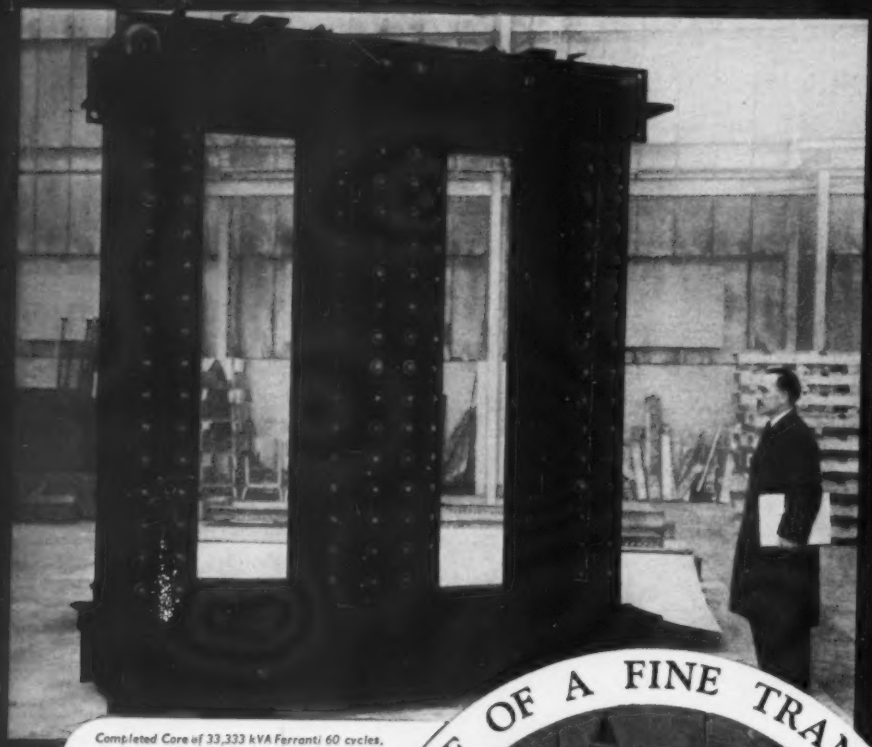

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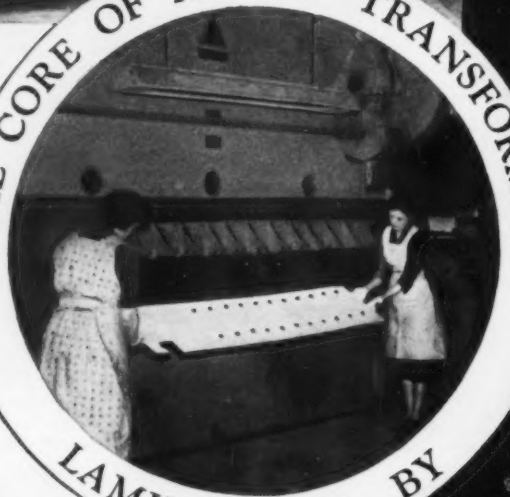

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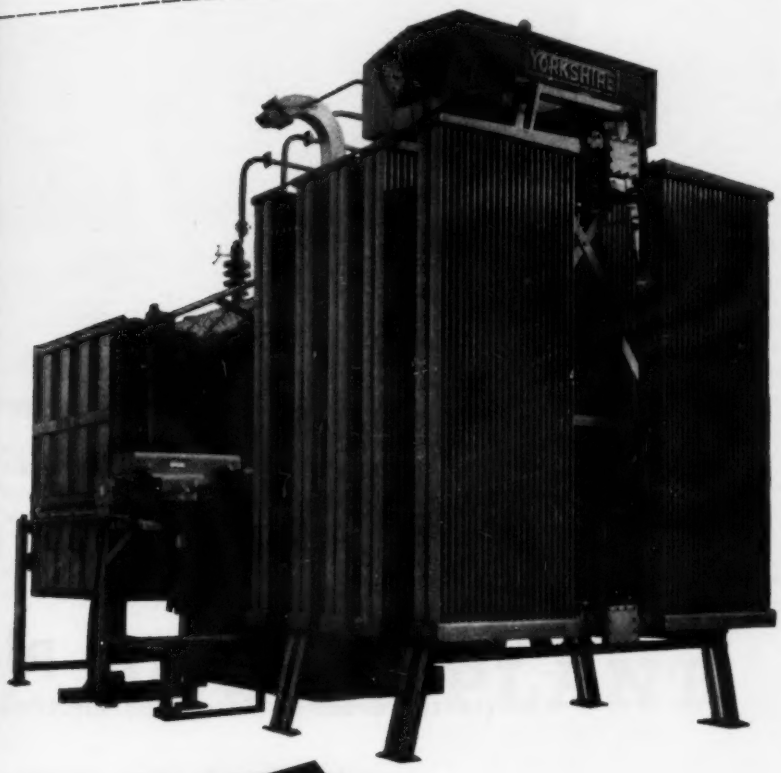

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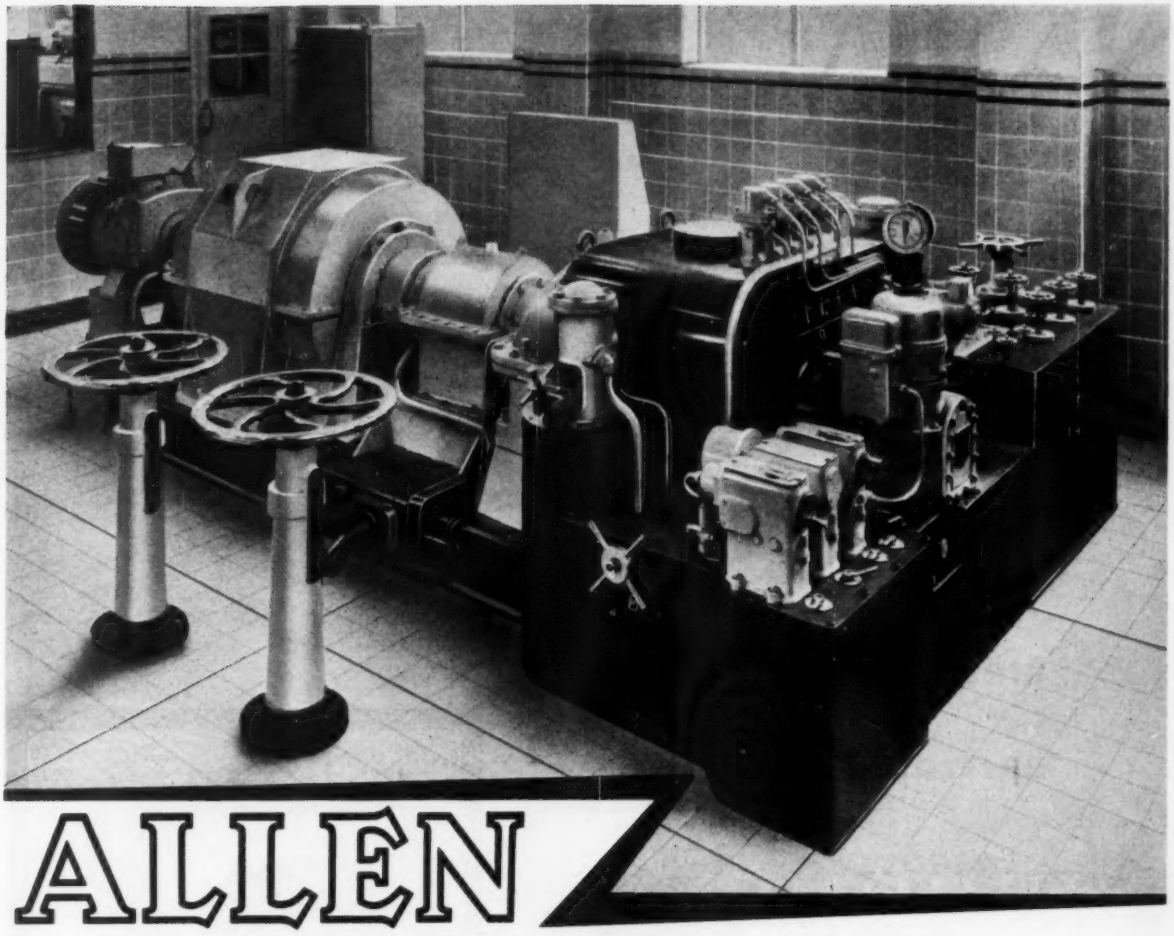

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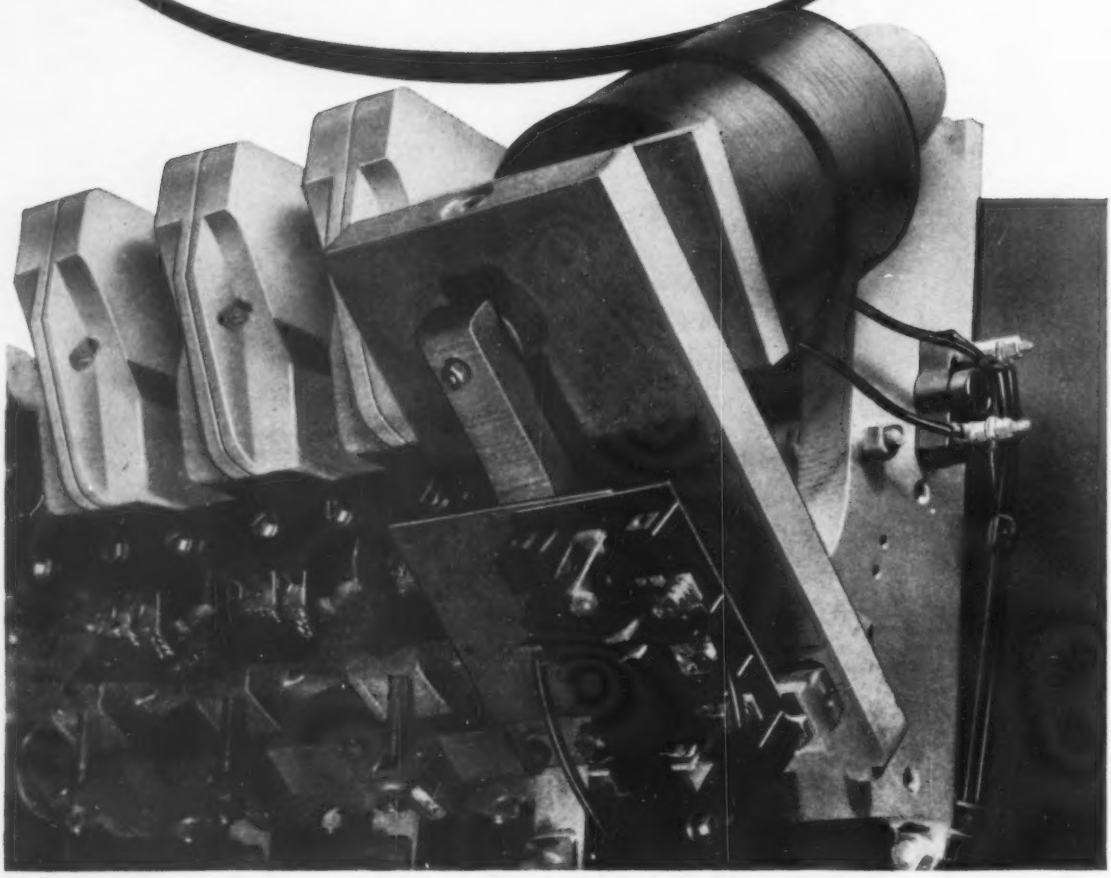

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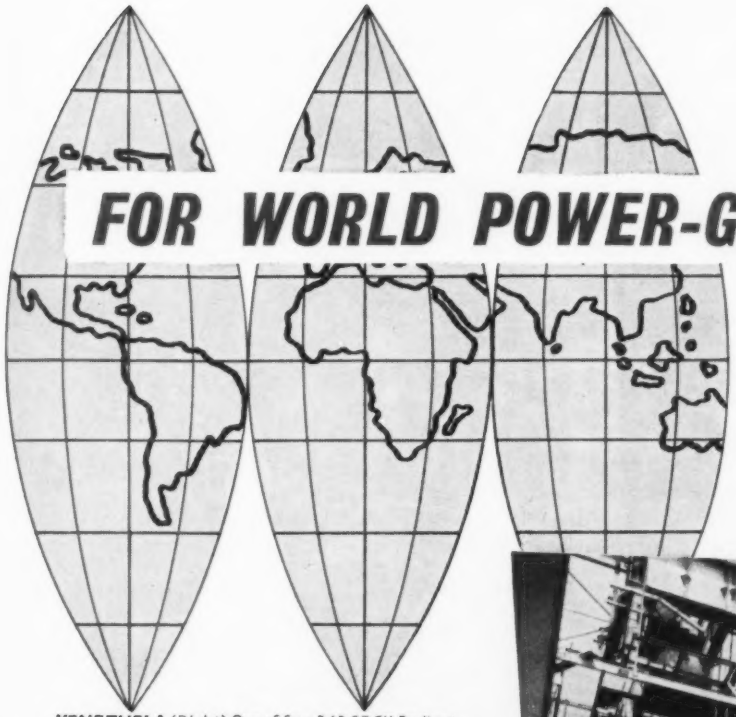

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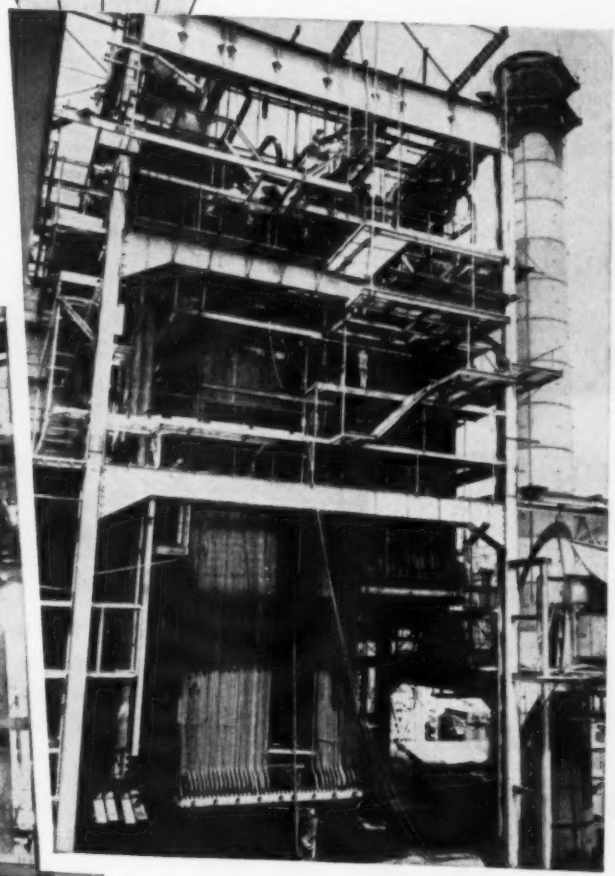
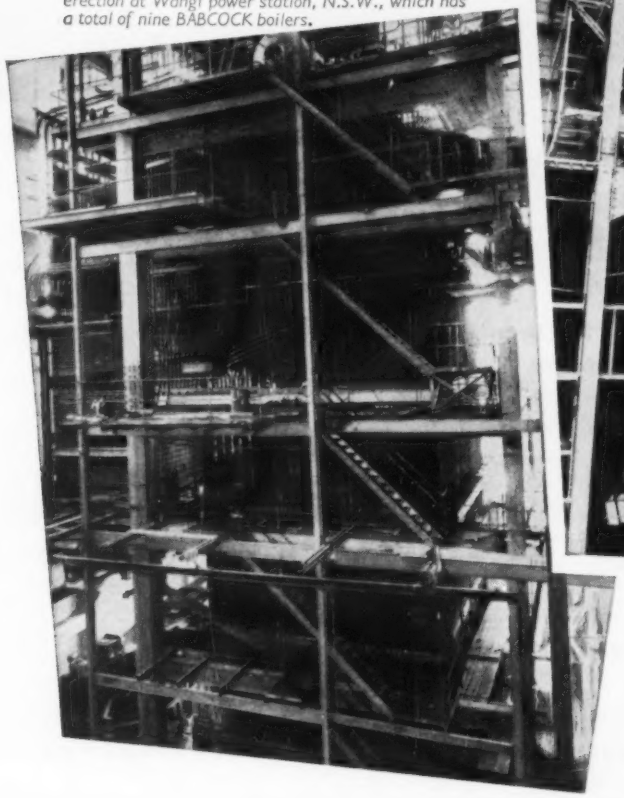
STEAM is, by far, the world's most important medium for electrical-power generation and a very high proportion of the world's power stations is equipped with BABCOCK steam-raising plant.



VENEZUELA (Right) *One of four BABCOCK Radiant boilers, natural-gas and oil fired, each rated at 550,000 lb./hr.; during erection for La Electricidad de Caracas. (Consulting Engineers: Sofina)*

AUSTRALIA (Below) *One of three BABCOCK Radiant boilers, each rated at 550,000 lb./hr.; during erection at Wangi power station, N.S.W., which has a total of nine BABCOCK boilers.*



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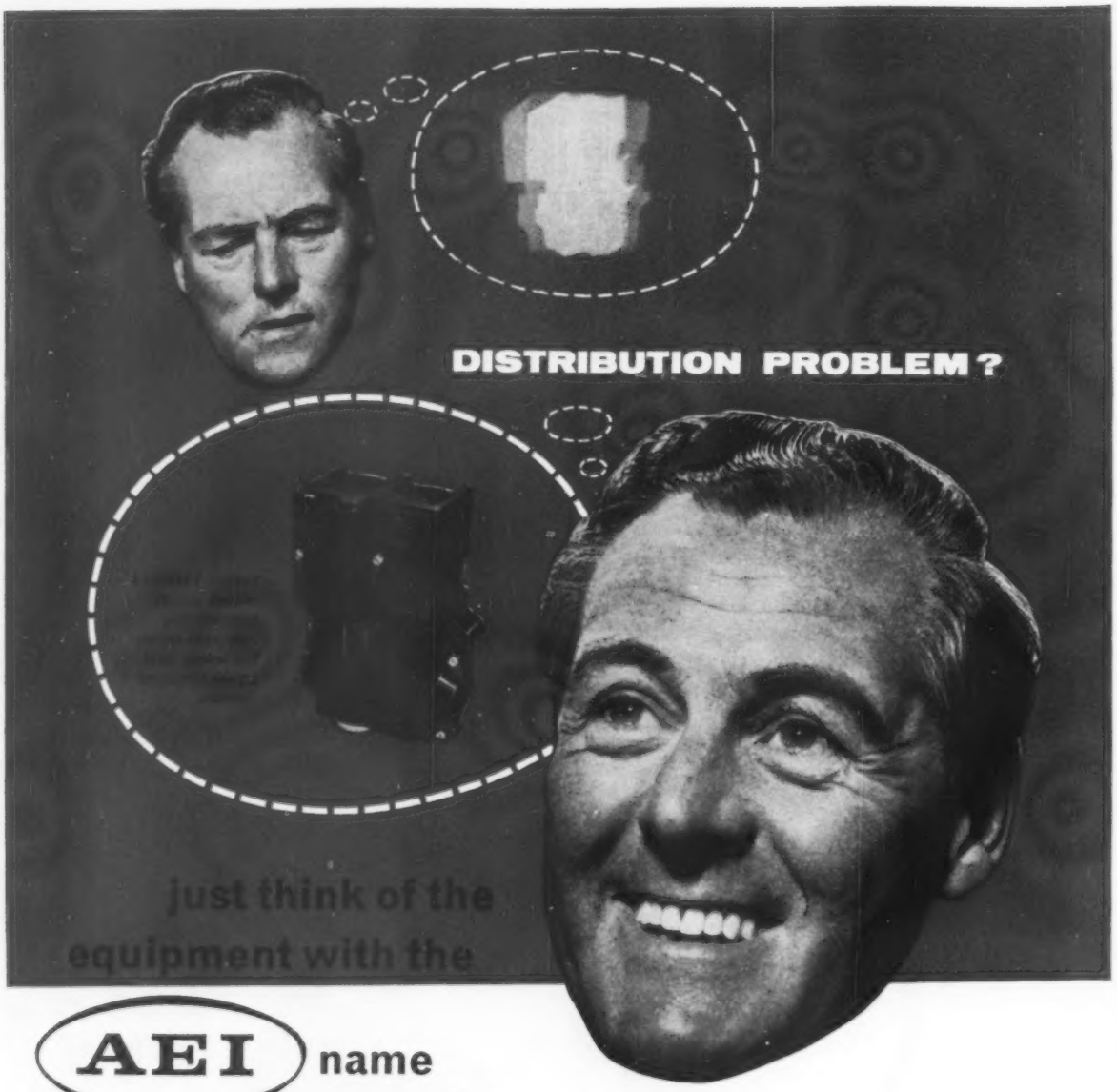

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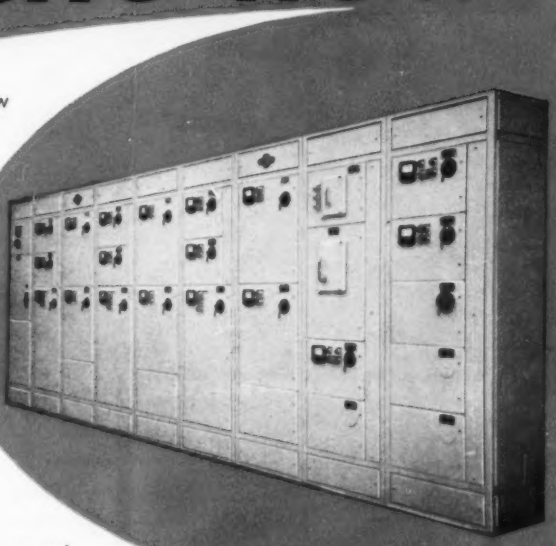
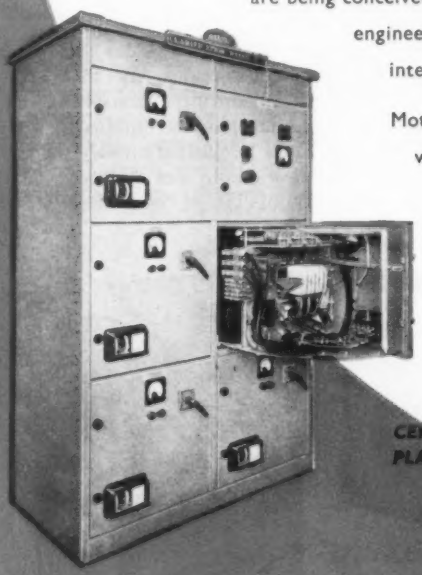
Production must flow in a steady stream . . . from material and component stock, through machinery or processing, to the finished stage.

The conveyors that speed this stream, the machines it feeds, the processing plant through which it passes . . . these, and the many main or ancillary equipments that serve the flow, are being conceived by today's engineers as studies in grouped or integrated control.





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BRUSH at the B·B·C

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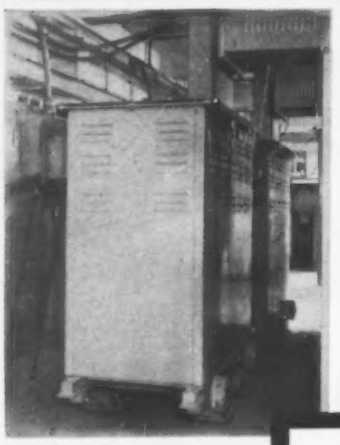
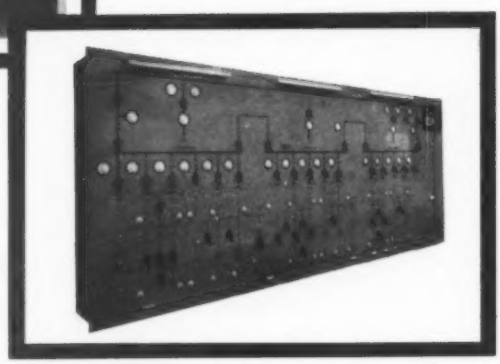


Two of the nine 750 kVA distribution Transformers.

The newly opened B.B.C. Television Centre at the White City consumes considerable electric power and requires a safe and dependable supply. Brush Control panels have been chosen for the three control rooms located within the studio area, controlling both 11 kV and 415 volt supplies. Brush have also supplied nine 750-kVA Transformers housed in Substations on the periphery of the new circular building. These dry type Transformers with Class 'C' insulation rely on surrounding air as the sole cooling medium and are able to withstand temperatures in excess of 180° C continuously.



Brush Control Panel in the Central Apparatus Room.

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A new and important advance
by Chloride Batteries Limited

Stand-by power in

½ the space

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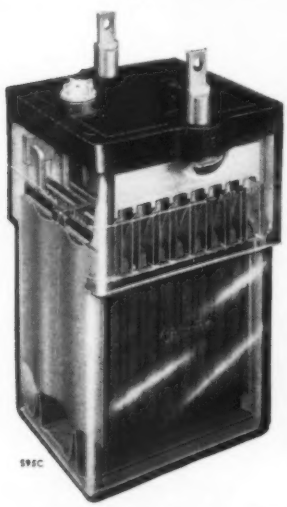
Chloride Stationary Cell

This new cell is specially designed for standby duties entailing discharge rates between, say, the 3-hour and the very high rates demanded for switch-closing purposes. With its Planté positive and pasted negative plates, Porvic microporous separators and many other improvements in material and in design, this light, robust cell will perform its duties with greater efficiency, with complete reliability and with a saving in battery space of approximately 50%. It is ideal for trickle-charge operation* and has all the remarkable length of life of the Planté type of construction. In Great Britain today standby batteries occupy millions of cubic feet of valuable space. The new Chloride cell could free almost half of it.



** The new cell will from now onwards be fitted in all Keepalite units—the Chloride Company's automatic emergency lighting system.*

By the makers of Exide Batteries

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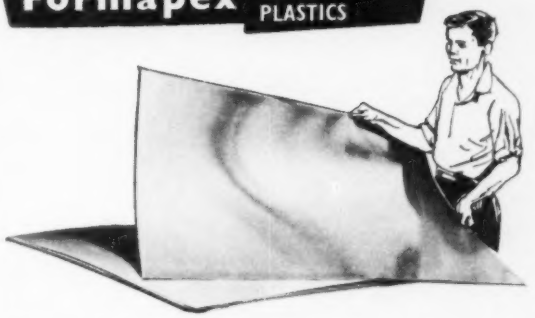

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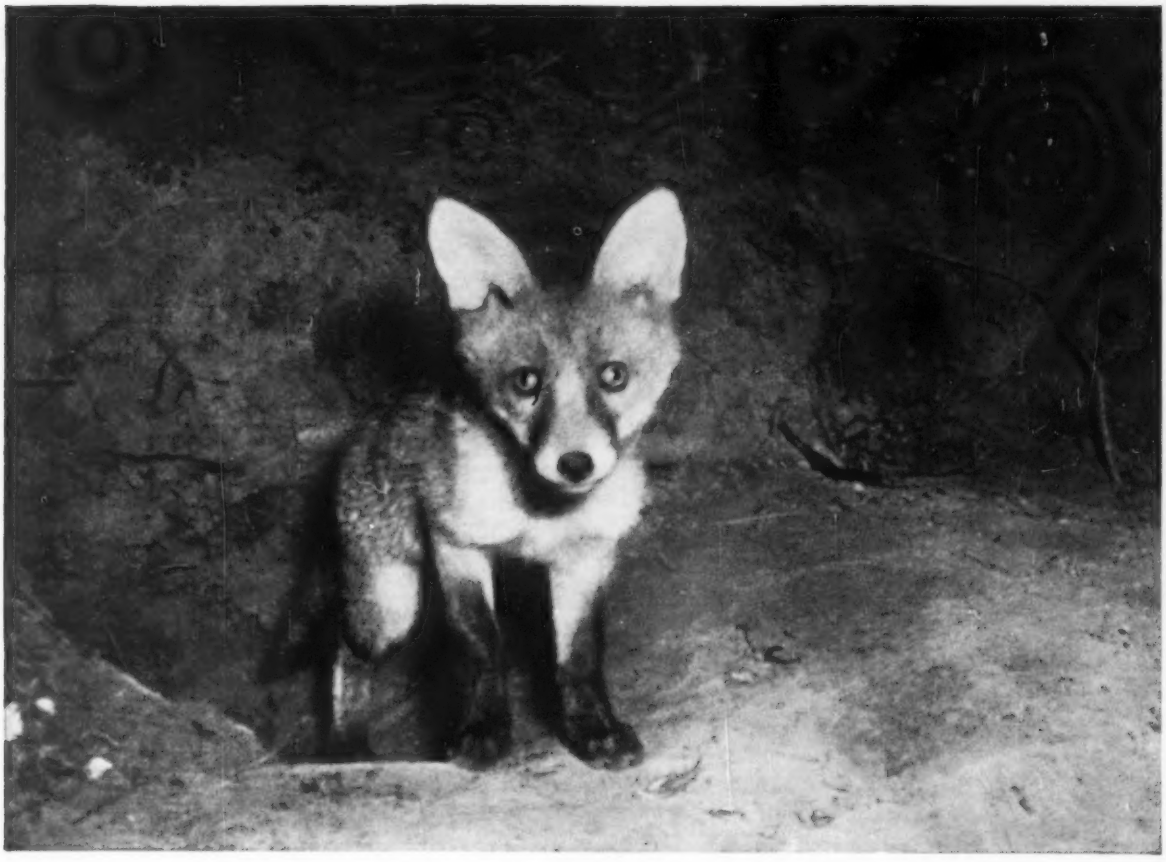

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First steps are important in all walks of life, as this fox cub emerging from his parental "earth" is already instinctively aware. And if he takes the wrong turning he can land up in serious trouble.

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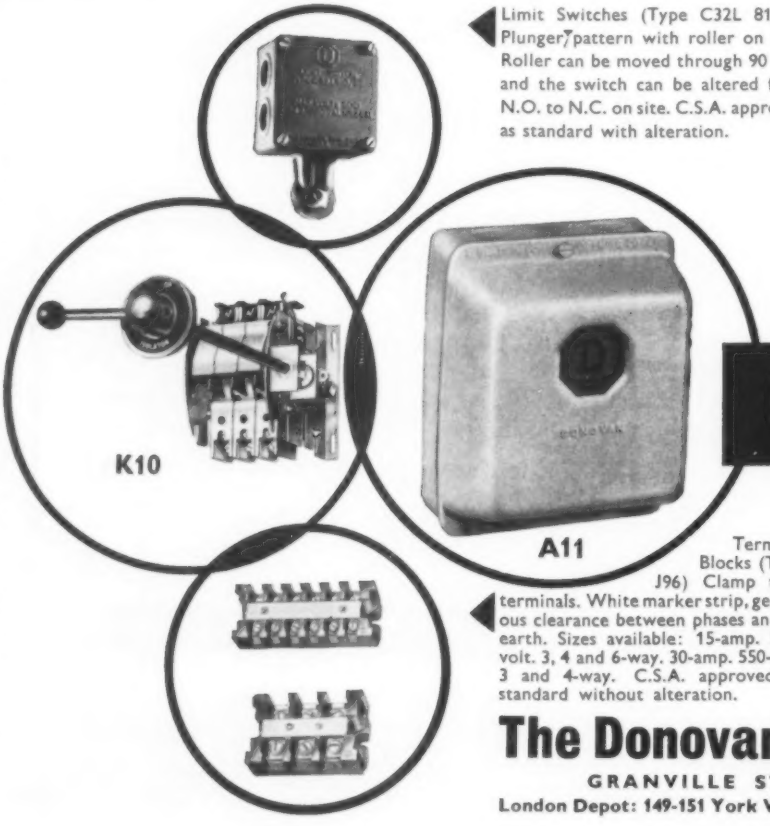

Limit Switches (Type C32L 810/1) Plunger pattern with roller on end. Roller can be moved through 90 deg. and the switch can be altered from N.O. to N.C. on site. C.S.A. approved as standard with alteration.

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Terminal Blocks (Type J96) Clamp type terminals. White marker strip, generous clearance between phases and to earth. Sizes available: 15-amp. 550-volt. 3, 4 and 6-way. 30-amp. 550-volt 3 and 4-way. C.S.A. approved as standard without alteration.

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Illustrated is a 4-pole enclosed relay.

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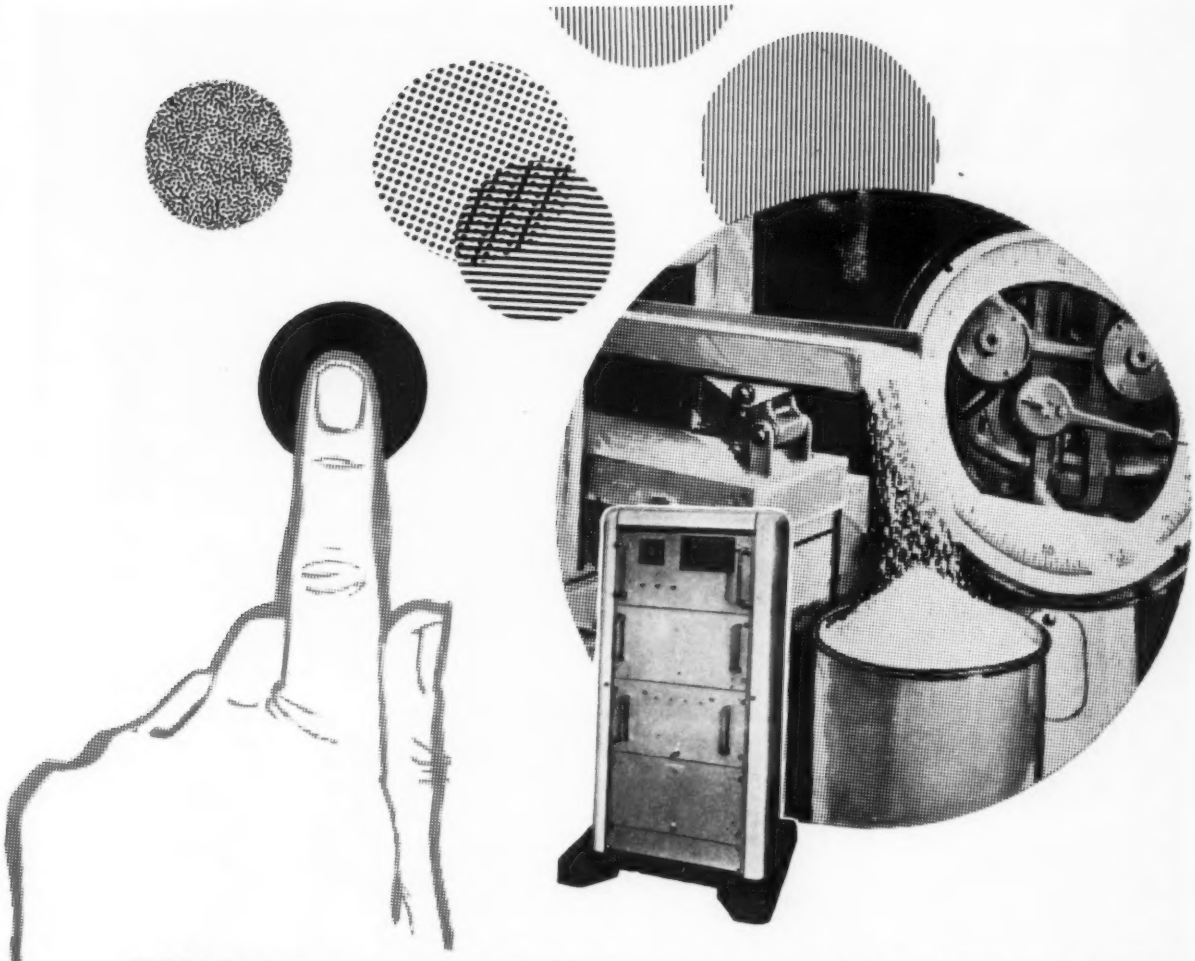

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* *Permanent data record printed out automatically*
* *Remote indications*
* *Tape or card control*

E.M.I. also designs and manufactures automatic control systems for:

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EMI

Please ask for details, or a demonstration of any of these systems.

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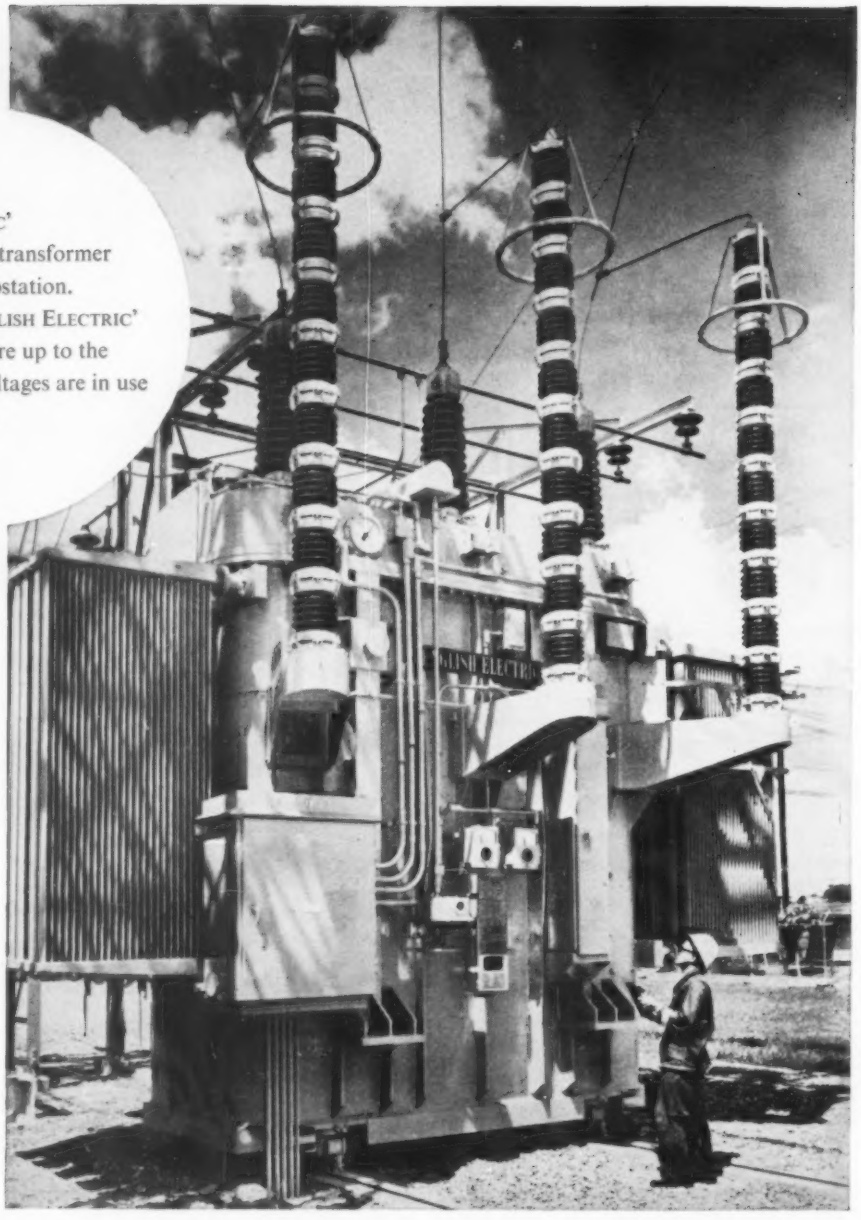

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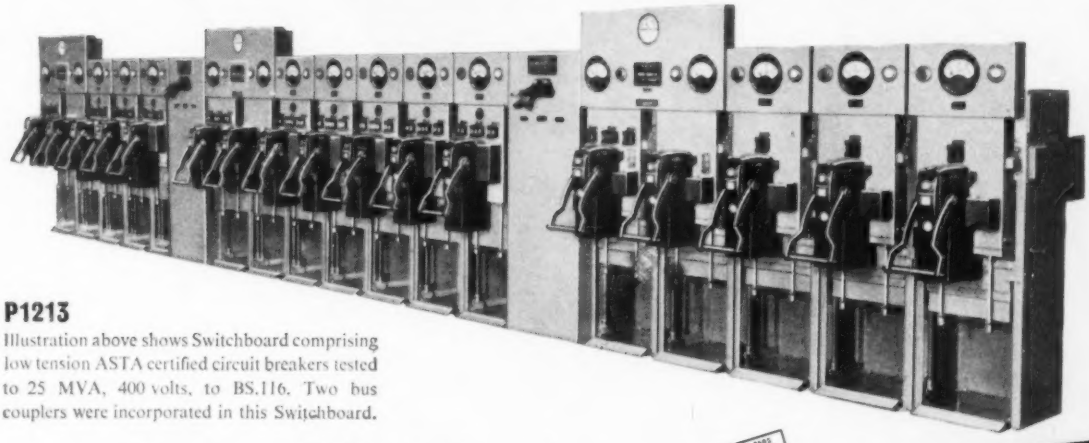
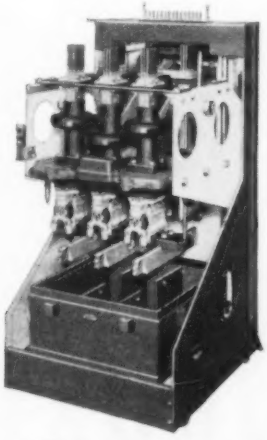
P.84

FOR HEAVY DUTY

THE MB RANGE OF CIRCUIT BREAKERS ILLUSTRATED BELOW HAS BEEN SHORT CIRCUIT TESTED AT AN ASTA STATION, THE LOW TENSION RANGE HAVING A CERTIFICATE FOR 25MVA, 400 VOLTS. THE 3·3 KV RANGE 75 MVA, ALL TO BS. 116.

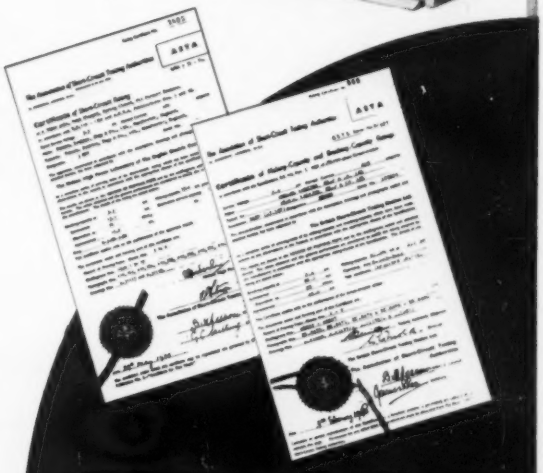


P1213
Illustration above shows Switchboard comprising low tension ASTA certified circuit breakers tested to 25 MVA, 400 volts, to BS.116. Two bus couplers were incorporated in this Switchboard.



P1245 The circuit breaker unit illustrated at the left is one of our 1600 amp. units of the same range as illustrated in the Switchboard above. It is of modern robust construction and suitable for controlling a 1000 kVA transformer. Our 1600 ampere unit has now been successfully tested at 31 M.V.A. 400 volts, to BS. 116.

May we have your enquiries ?



ILLUSTRATED ABOVE ARE TWO OF THE MANY ASTA CERTIFICATES WHICH WE HOLD AND REFER TO OUR LOW TENSION 400 VOLT AND 3·3KV MB TYPE SWITCHGEAR.

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CABLES

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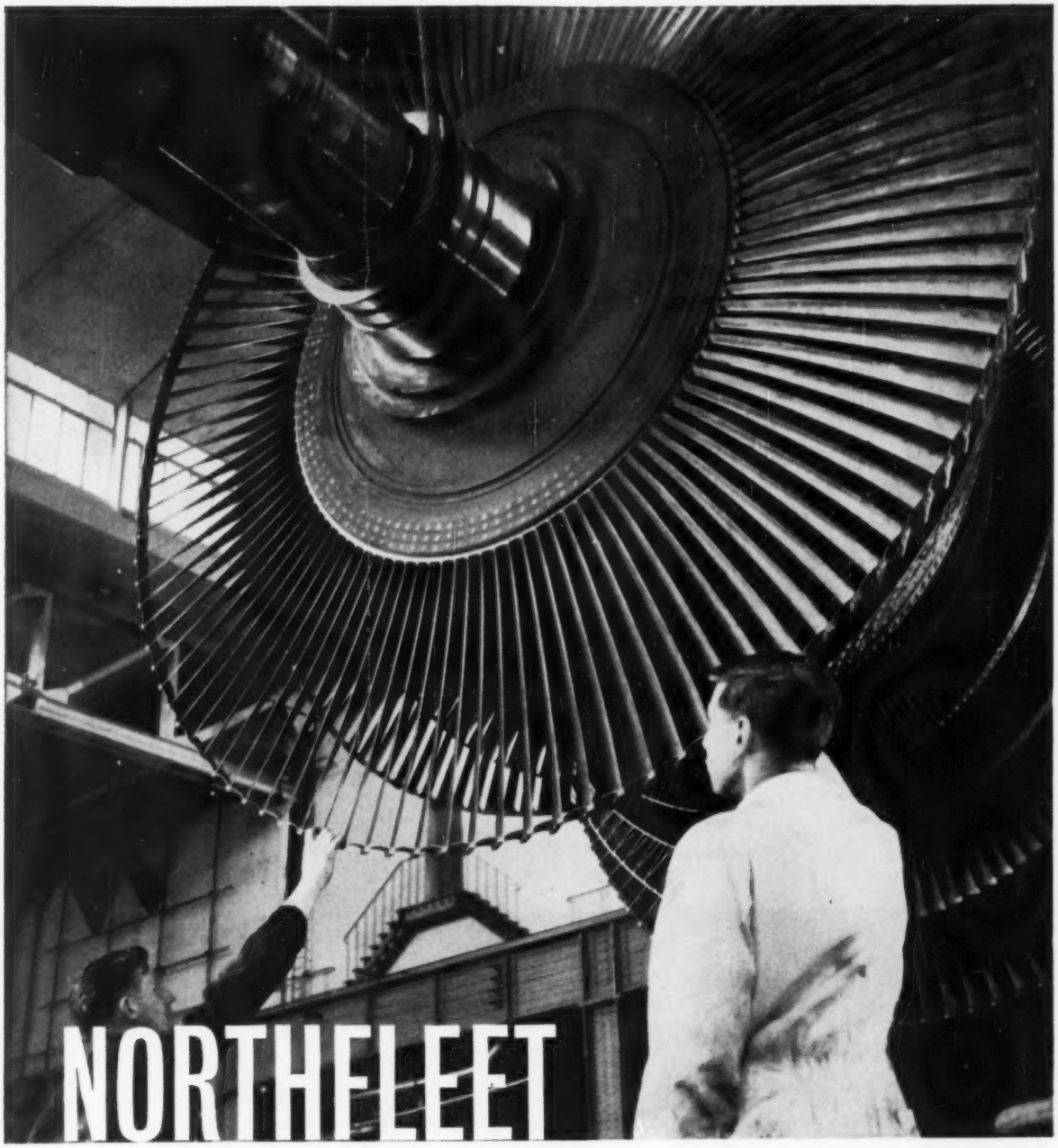


G.E.C. is installing six 120 MW reheat turbo-generators in the Northfleet Power Station of the Central Electricity Generating Board.

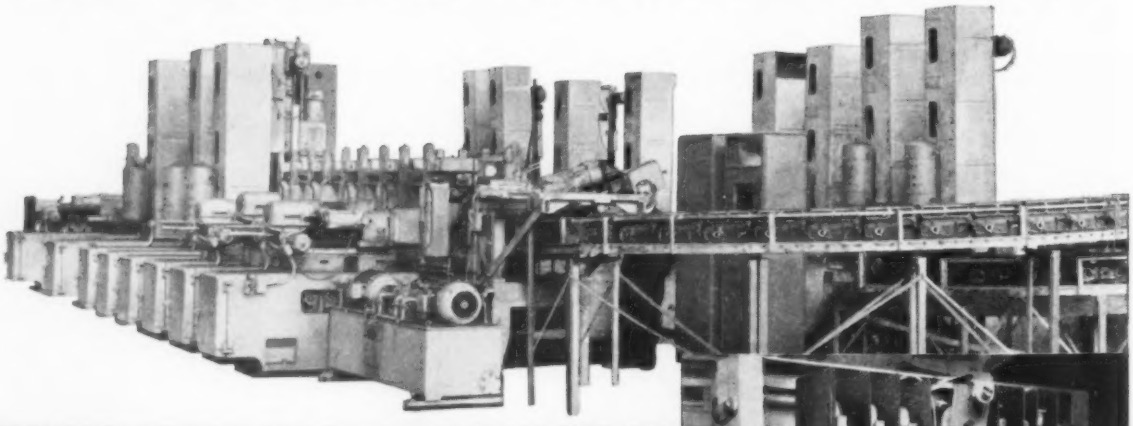
G.E.C.

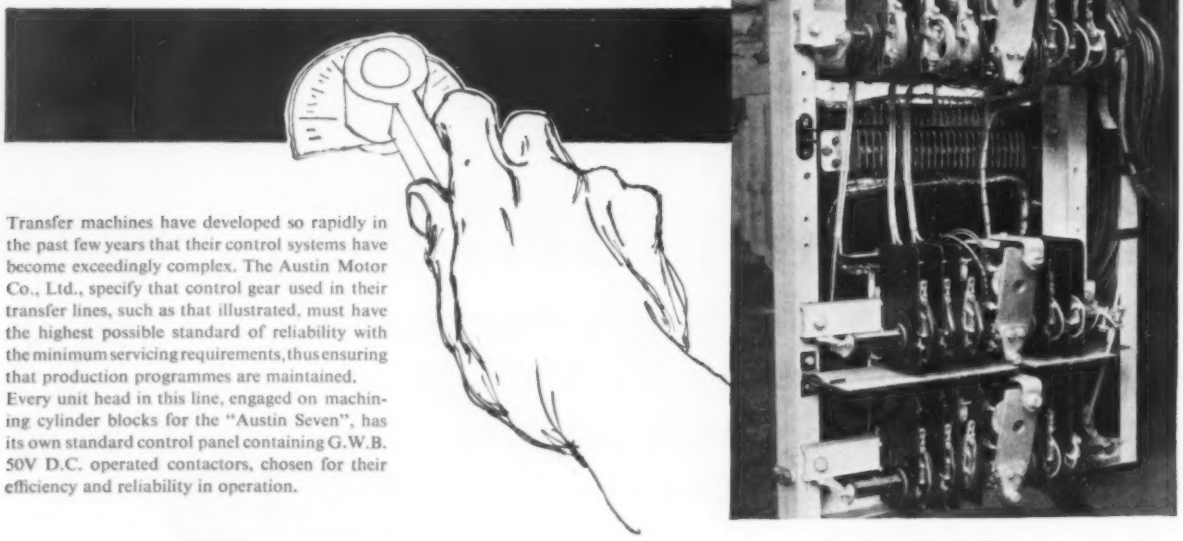
THE GENERAL ELECTRIC CO LTD OF ENGLAND POWER PLANT DIVISION ERITH KENT

374

AUSTIN

USE G.W.B. CONTROL GEAR





Transfer machines have developed so rapidly in the past few years that their control systems have become exceedingly complex. The Austin Motor Co., Ltd., specify that control gear used in their transfer lines, such as that illustrated, must have the highest possible standard of reliability with the minimum servicing requirements, thus ensuring that production programmes are maintained. Every unit head in this line, engaged on machining cylinder blocks for the "Austin Seven", has its own standard control panel containing G.W.B. 50V D.C. operated contactors, chosen for their efficiency and reliability in operation.

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more than 200,000 operations with

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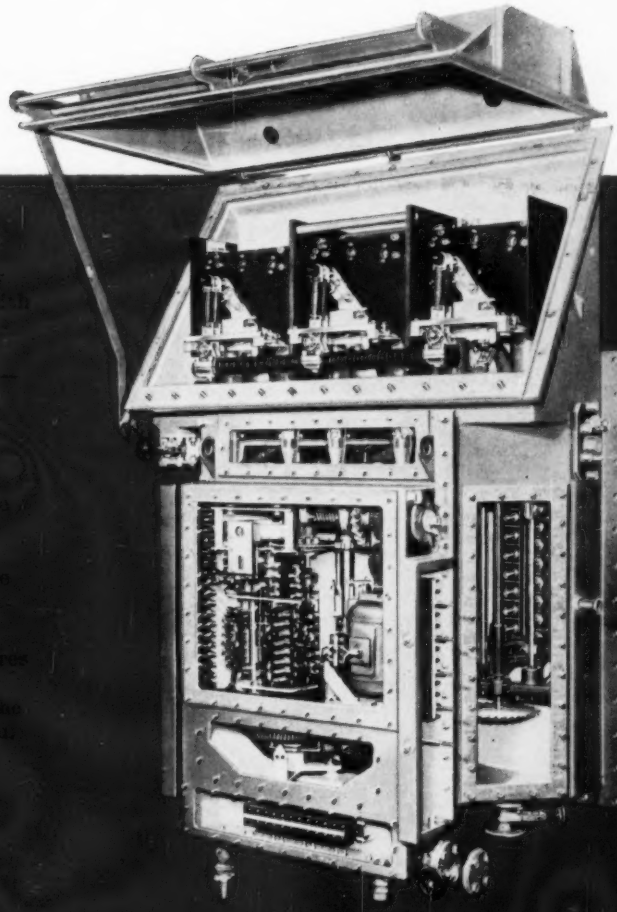
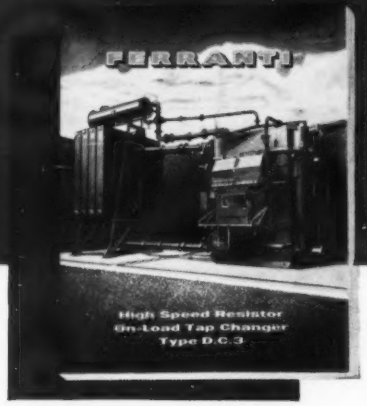


FERRANTI
High Speed Resistor
On-Load Tap Changer
Type D.C.3



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FT 241/2

It's aluminium

Sheathed in *seamless* extruded aluminium, this cable is lightweight yet strong. It needs no armouring, thus allowing simple cable design. With a high resistance to vibration fatigue, it can be uased with complete safety, alongside railways etc.

It's flexible

Corrugation results in greater flexibility, permitting the same bending radius as a lead sheathed cable. Not only are handling qualities improved but corrugation reduces the required thickness of the sheath *by one half*.

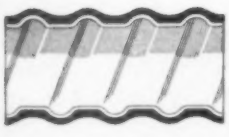
It's a money saver

Initial costs are therefore lower than conventional type cables of similar performance. Lightness and flexibility simplify transportation and installation. No special precautions are necessary to allow for expansion and contraction.

Further information is available on request.

It's the BICC C.S.A. cable

CORRUGATED
SEAMLESS
ALUMINIUM



PROTECTIVE SERVING

Anti-corrosion protection is provided by an extruded P.V.C. covering which fits tightly over the whole sheath surface. *See section view.*

INSTALLATION

Conventional installation procedure is followed. Jointing techniques are the same as for normal smooth aluminium-sheathed cables.

CABLE TYPES

C.S.A. sheathing is available with BICC Mass - Impregnated Non - Draining (M.I.N.D.) Cables up to 33kV and for Oil-Filled Cables.

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